

# PIPING: Uses, and Plant Construction

## USES OF PIPING

### 1.1

Piping is used for industrial (process), marine, transportation, civil engineering, and for 'commercial' (plumbing) purposes.

This book is primarily concerned with industrial piping for processing and service systems. *Process piping* is used to transport fluids between storage tanks and processing units. *Service piping* is used to convey steam, air, water, etc., for processing. Piping here defined as 'service' piping is sometimes referred to as 'utility' piping, but, in the Guide, the term 'utility piping' is reserved for major lines supplying water, fuel gases, and fuel oil (that is, for commodities usually purchased from utilities companies and bulk suppliers).

*Marine piping* for ships is often extensive. Much of it is fabricated from welded and screwed carbon-steel piping, using pipe and fittings described in this book.

*Transportation piping* is normally large-diameter piping used to convey liquids, slurries and gases, sometimes over hundreds of miles. Crude oils, petroleum products, water, and solid materials such as coal (carried by water) are transported thru pipelines. Different liquids can be transported consecutively in the same pipeline, and branching arrangements are used to divert flows to different destinations.

*Civil piping* is used to distribute public utilities (water, fuel gases), and to collect rainwater, sewage, and industrial waste waters. Most piping of this type is placed underground.

*Plumbing (commercial piping)* is piping installed in commercial buildings, schools, hospitals, residences, etc., for distributing water and fuel gases, for collecting waste water, and for other purposes.

## COMMISSIONING, DESIGNING, & BUILDING A PLANT

### 1.2

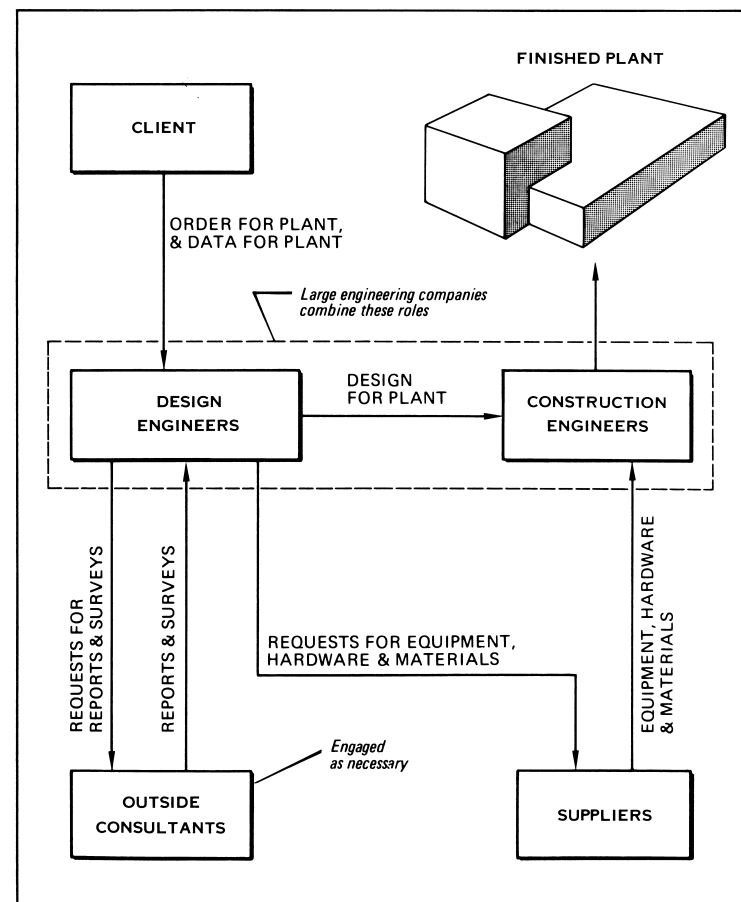
When a manufacturer decides to build a new plant, or to expand an existing one, the manufacturer will either employ an engineering company to undertake design and construction, or, if the company's own engineering department is large enough, they will do the design work, manage the project, and employ one or more contractors to do the construction work.

In either procedure, the manufacturer supplies information concerning the purposes of buildings, processes, production rates, design criteria for specific requirements, details of existing plant, and site surveys, if any.

Chart 1.1 shows the principals involved, and the flow of information and material.

SCHEMATIC FOR PLANT CONSTRUCTION

CHART 1.1



The designing and building of an industrial plant is a complex undertaking. Except for the larger industrial concerns, who may maintain their own design staffs, the design and construction of plants and related facilities is usually undertaken by specialist companies.

The Guide describes in 4.1 the organization and responsibilities of design engineering, with special reference to the duties of individuals engaged in the development of piping designs for plants.

# PIPE, FITTINGS, FLANGES, REINFORCEMENTS, In-line Equipment and Support Equipment

## PROCESS PIPE

### 2.1

### PIPE & TUBE

#### 2.1.1

Tubular products are termed 'tube' or 'pipe'. Tube is customarily specified by its outside diameter and wall thickness, expressed either in BWG (Birmingham wire gage) or in thousandths of an inch. Pipe is customarily identified by 'nominal pipe size', with wall thickness defined by 'schedule number', 'API designation', or 'weight', as explained in 2.1.3. Non-standard pipe is specified by nominal size with wall thickness stated.

The principal uses for tube are in heat exchangers, instrument lines, and small interconnections on equipment such as compressors, boilers, and refrigerators.

### SIZES & LENGTHS COMMONLY USED FOR STEEL PIPE

#### 2.1.2

ANSI standard B36.10M establishes wall thicknesses for pipe ranging from 1/8 to 80-inch nominal diameter ('nominal pipe size'). Pipe sizes normally stocked include: 1/2, 3/4, 1, 1¼, 1½, 2, 2½, 3, 3½, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20 and 24. Sizes 1¼, 2½, 3½, and 5 inch are seldom used (unusual sizes are sometimes required for connecting to equipment, but piping is normally run in the next larger stock size after connection has been made). 1/8, 1/4, 3/8 and 1/2-inch pipe is usually restricted to instrument lines or to service and other lines which have to mate with equipment. 1/2-inch pipe is extensively used for steam tracing and for auxiliary piping at pumps, etc.

Straight pipe is supplied in 'random' lengths (17 to 25 ft), and sometimes 'double random' lengths (38 to 48 ft), if preferred. The ends of these lengths are normally either plain (PE), beveled for welding (BE), or threaded and supplied with one coupling per length ('threaded and coupled', or 'T&C'). If pipe is ordered 'T&C', the rating of the coupling is specified—see chart 2.3. Other types of ends, such as grooved for special couplings, can be obtained to order.

### DIAMETERS & WALL THICKNESSES OF PIPE

#### 2.1.3

The size of all pipe is identified by the nominal pipe size, abbreviated 'NPS', which is seldom equal to the true bore (internal diameter) of the pipe—the difference in some instances is large. NPS 14 and larger pipe has outside diameter equal to the nominal pipe size.

Pipe in the various sizes is made in several wall thicknesses for each size, which have been established by three different sources:—

- (1) The American National Standards Institute, thru 'schedule numbers'
- (2) The American Society of Mechanical Engineers and the American Society for Testing and Materials, thru the designations 'STD' (standard), 'XS' (extra-strong), and 'XXS' (double-extra-strong), drawn from dimensions established by manufacturers. *In the Guide, these designations are termed 'manufacturers' weights'*
- (3) The American Petroleum Institute, through its standard 5L, for 'Line pipe'. Dimensions in this standard have no references for individual sizes and wall thicknesses

'Manufacturers' weights' (second source) were intended, as long ago as 1939, to be superseded by schedule numbers. However, demand for these wall thicknesses has caused their manufacture to continue. Certain fittings are available only in manufacturers' weights.

Pipe dimensions from the second and third sources are incorporated in American National Standard B36.10M. Tables P-1 list dimensions for welded and seamless steel pipe in this standard, and give derived data.

**IRON PIPE SIZES** were initially established for wrought-iron pipe, with wall thicknesses designated by the terms 'standard (weight)', 'extra-strong', and 'double-extra-strong'. Before the schedule number scheme for steel pipe was first published by the American Standards Association in 1935, the iron pipe sizes were modified for steel pipe by slightly decreasing the wall thicknesses (leaving the outside diameters constant) so that the weights per foot (lb/ft) equalled the iron pipe weights.

Wrought-iron pipe (no longer made) has been completely supplanted by steel pipe, but schedule numbers, intended to supplant iron pipe designations did not. Users continued to specify pipe in iron pipe terms, and as the mills responded, these terms are included in ANSI standard B36.10M for steel pipe. Schedule numbers were introduced to establish pipe wall thicknesses by formula, but as wall thicknesses in common use continued to depart from those proposed by the scheme, schedule numbers now identify wall thicknesses of pipe in the different nominal sizes as ANSI B36.10M states "as a convenient designation system for use in ordering".

**STAINLESS-STEEL SIZES** American National Standard B36.19 established a range of thin-walled sizes for stainless-steel pipe, identified by schedules 5S and 10S.

## MATERIALS FOR PIPE

### 2.1.4

**STEEL PIPE** Normally refers to carbon-steel pipe. Seam-welded steel pipe is made from plate. Seamless pipe is made using dies. Common finishes are 'black' ('plain' or 'mill' finish) and galvanized.

Correctly selected steel pipe offers the strength and durability required for the application, and the ductility and machinability required to join it and form it into piping ('spools' -- see 5.2.9). The selected pipe must withstand the conditions of use, especially pressure, temperature and corrosion conditions. These requirements are met by selecting pipe made to an appropriate standard; in almost all instances an ASTM or API standard (see 2.1.3 and table 7.5).

The most-used steel pipe for process lines, and for welding, bending, and coiling, is made to ASTM A-53 or ASTM A-106, principally in wall thicknesses defined by schedules 40, 80, and manufacturers' weights, STD and XS. Both ASTM A-53 and ASTM A-106 pipe is fabricated seamless or seamed, by electrical resistance welding, in Grades A and B. Grades B have the higher tensile strength. Three grades of A-106 are available—Grades A, B, and C, in order of increasing tensile strength.

The most widely stocked pipe is to ASTM A-120 which covers welded and seamless pipe for normal use in steam, water, and gas (including air) service. ASTM A-120 is not intended for bending, coiling or high temperature service. It is not specified for hydrocarbon process lines.

In the oil and natural gas industries, steel pipe used to convey oil and gas is manufactured to the American Petroleum Institute's standard API 5L, which applies tighter control of composition and more testing than ASTM-120.

Steel specifications in other countries may correspond with USA specifications. Some corresponding european standards for carbon steels and stainless steels are listed in table 2.1.

**IRON** pipe is made from cast-iron and ductile-iron. The principal uses are for water, gas, and sewage lines.

**OTHER METALS & ALLOYS** Pipe or tube made from copper, lead, nickel, brass, aluminum and various stainless steels can be readily obtained. These materials are relatively expensive and are selected usually either because of their particular corrosion resistance to the process chemical, their good heat transfer, or for their tensile strength at high temperatures. Copper and copper alloys are traditional for instrument lines, food processing, and heat transfer equipment, but stainless steels are increasingly being used for these purposes.

**PLASTICS** Pipe made from plastics may be used to convey actively corrosive fluids, and is especially useful for handling corrosive or hazardous gases and dilute mineral acids. Plastics are employed in three ways: as all-plastic pipe, as 'filled' plastic materials (glass-fiber-reinforced, carbon-filled, etc.) and as lining or coating materials. Plastic pipe is made from polypropylene, polyethylene (PE), polybutylene (PB), polyvinyl chloride (PVC), acrylonitrile-butadiene-styrene (ABS), cellulose acetate-butyrates (CAB), polyolefins, and polyesters. Pipe made from polyester and epoxy resins is frequently glass-fiber-reinforced ('FRP') and commercial products of this type have good resistance to wear and chemical attack.

| COMPARABLE USA & EUROPEAN SPECIFICATIONS FOR STEEL PIPE |   |   |  | TABLE 2.1  |
|---|---|---|--|--|
|   | USA   | UK  | W. GERMANY   | SWEDEN   |
| CARBON-STEEL PIPE                                       | <b>ASTM A53</b><br>Grade A SMLS<br>Grade B SMLS   | <b>BS 3601</b><br>HFS 22 & CDS 22<br>HFS 27 & CDS 27                              | <b>DIN 1629</b><br>St 35<br>St 45  | SIS 1233-05<br>SIS 1434-05                               |
|   | <b>ASTM A53</b><br>Grade A ERW<br>Grade B ERW   | <b>BS 3601</b><br>ERW 22<br>ERW 27  | <b>DIN 1626</b><br>Blatt 3 St 34-2 ERW<br>Blatt 3 St 37-2 ERW  |  |
|   | <b>ASTM A53</b><br>FBW  | <b>BS 3601</b><br>BW 22   | <b>DIN 1626</b><br>Blatt 3 St 34-2 FBW   |  |
|   | <b>ASTM A106</b><br>Grade A<br>Grade B<br>Grade C                                       | <b>BS 3602</b><br>HFS 23<br>HFS 27<br>HFS 35                                      | <b>DIN 17175*</b><br>St 35-8<br>St 45-8  | SIS 1234-05<br>SIS 1435-05                               |
|   | <b>ASTM A134</b>  | <b>BS 3601</b><br>EFW   | <b>DIN 1626</b><br>Blatt 2 EFW   |  |
|   | <b>ASTM A135</b><br>Grade A<br>Grade B  | <b>BS 3601</b><br>ERW 22<br>ERW 27  | <b>DIN 1626</b><br>Blatt 3 St 34-2 ERW<br>Blatt 3 St 37-2 ERW  | SIS 1233-06<br>SIS 1434-06                               |
|   | <b>ASTM A139</b><br>Grade A<br>Grade B  | <b>BS 3601</b><br>EFW 22<br>EFW 27  | <b>DIN 1626</b><br>Blatt 2 St 37<br>Blatt 2 St 42  |  |
|   | <b>ASTM A155</b><br>Class 2<br>C 45<br>C 50<br>C 55<br>KC 55<br>KC 60<br>KC 65<br>KC 70 | <b>BS 3602</b><br><br><br><br>EFW 28<br><br>EFW 28S                               | <b>DIN 1626, Blatt 3, with certification C</b><br>St 34-2<br>St 37-2<br>St 42-2<br>St 42-2 *<br>St 52-3<br>St 52-3           |  |
|   | <b>API 5L</b><br>Grade A SMLS<br>Grade B SMLS   | <b>BS 3601</b><br>HFS 22 & CDS 22<br>HFS 27 & CDS 27                              | <b>DIN 1629</b><br>St 35<br>St 45  | SIS 1233-05<br>SIS 1434-05                               |
|   | <b>API 5L</b><br>Grade A ERW<br>Grade B ERW   | <b>BS 3601</b><br>ERW 22<br>ERW 27 †  | <b>DIN 1625</b><br>Blatt 3 St 34-2 ERW<br>Blatt 4 St 37-2 ERW  | SIS 1233-06<br>SIS 1434-06 †                             |
| STAINLESS-STEEL PIPE                                    | <b>API 5L</b><br>Grade A EFW<br>Grade B EFW   | <b>BS 3601</b><br>Double-welded<br>EFW 22<br>EFW 27 †                             | <b>DIN 1626</b><br>Blatt 3 St 34-2 FW<br>Blatt 4 St 37-2 FW  |  |
|   | <b>API 5L</b><br>FBW  | <b>BS 3601</b><br>BW 22   | <b>DIN 1626</b><br>Blatt 3 St 34-2 FBW   |  |
|   | *Specify "Si-killed" †Specify API 5L Grade B testing procedures for these steels        |   |  |  |
|   | <b>ASTM A312</b><br>TP 304<br>TP 304H<br>TP 304L<br>TP 310<br>TP 316                    | <b>BS 3605</b><br>Grade 801<br>Grade 811<br>Grade 801 L<br>Grade 805<br>Grade 845 | <b>WSN Designation:</b><br>4301 X 5 CrNi 18 9<br>4306 X 2 CrNi 18 9<br>4841 X 15 CrNiSi 25 20<br>4401/ 4436 X 5 CrNiMo 18 10 | SIS 2333-02<br>SIS 2352-02<br>SIS 2361-02<br>SIS 2343-02 |
|   | TP 316H<br>TP 316L<br>TP 317  | Grade 855<br>Grade 845L<br>Grade 846  | 4404 X 2 CrNiMo 18 10  | SIS 2353-02  |
|   | TP 321<br>TP 321H<br>TP 347<br>TP 347H  | Grade 822 Ti<br>Grade 832 Ti<br>Grade 822 Nb<br>Grade 832 Nb                      | 4541 X 10 CrNiTi 18 9<br>4550 X 10 CrNiNb 18 9   | SIS 2337-02<br>SIS 2338-02                               |
|   |   |   |  |  |
|   |   |   |  |  |
|   |   |   |  |  |
|   |   |   |  |  |

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The American National Standards Institute has introduced several schedules for pipe made from various plastics. These ANSI standards and others for plastic pipe are listed in table 7.5.

**GLASS** All-glass piping is used for its chemical resistance, cleanliness and transparency. Glass pipe is not subject to 'crazing' often found in glass-lined pipe and vessels subject to repeated thermal stresses. Pipe, fittings, and hardware are available both for process piping and for drainage. Corning Glass Works offers a Pyrex 'Conical' system for process lines in 1, 1½, 2, 3, 4 and 6-inch sizes (ID) with 450 F as the maximum operating temperature, and pressure ranges 0–65 PSIA (1 in. thru 3 in.), 0–50 PSIA (4 in.) and 0–35 PSIA (6 in.). Glass cocks, strainers and thermowells are available. Pipe fittings and equipment are joined by flange assemblies which bear on the thickened conical ends of pipe lengths and fittings. Corning also offers a Pyrex Acid-Waste Drainline system in 1½, 2, 3, 4 and 6-inch sizes (ID) with beaded ends joined by Teflon-gasketed nylon compression couplings. Both Corning systems are made from the same borosilicate glass.

**LININGS & COATINGS** Lining or coating carbon-steel pipe with a material able to withstand chemical attack permits its use to carry corrosive fluids. Lengths of lined pipe and fittings are joined by flanges, and elbows, tees, etc., are available already flanged. Linings (rubber, for example) can be applied after fabricating the piping, but pipe is often pre-lined, and manufacturers give instructions for making joints. Linings of various rubbers, plastics, metals and vitreous (glassy) materials are available. Polyvinyl chloride, polypropylene and copolymers are the most common coating materials. Carbon-steel pipe zinc-coated by immersion into molten zinc (hot-dip galvanized) is used for conveying drinking water, instrument air and various other fluids. Rubber lining is often used to handle abrasive fluids.

## TEMPERATURE & PRESSURE LIMITS 2.1.5

Carbon steels lose strength at high temperatures. Electric-resistance-welded pipe is not considered satisfactory for service above 750 F, and furnace-butt-welded pipe above about 650 F. For higher temperatures, pipe made from stainless steels or other alloys should be considered.

Pressure ratings for steel pipe at different temperatures are calculated according to the ANSI B31 Code for Pressure Piping (detailed in table 7.2). ANSI B31 gives stress/temperature values for the various steels from which pipe is fabricated.

## METHODS FOR JOINING PIPE 2.2

The joints used for most carbon-steel and stainless-steel pipe are:

|                               |                                     |
|-------------------------------|-------------------------------------|
| <b>BUTT-WELDED</b>            | <b>SEE 2.3</b>                      |
| <b>SOCKET-WELDED</b>          | <b>SEE 2.4</b>                      |
| <b>SCREWED</b>                | <b>SEE 2.5</b>                      |
| <b>BOLTED FLANGE</b>          | <b>SEE 2.3.1, 2.4.1 &amp; 2.5.1</b> |
| <b>BOLTED QUICK COUPLINGS</b> | <b>SEE 2.8.2</b>                    |

## WELDED & SCREWED JOINTS 2.2.1

Lines NPS 2 and larger are usually butt-welded, this being the most economic leakproof way of joining larger-diameter piping. Usually such lines are subcontracted to a piping fabricator for prefabrication in sections termed 'spools', then transported to the site. Lines NPS 1½ and smaller are usually either screwed or socket-welded, and are normally field-run by the piping contractor from drawings. Field-run and shop-fabricated piping are discussed in 5.2.9.

## SOCKET-WELDED JOINTS 2.2.2

Like screwed piping, socket welding is used for lines of smaller sizes, but has the advantage that absence of leaking is assured: this is a valuable factor when flammable, toxic, or radioactive fluids are being conveyed—the use of socket-welded joints is not restricted to such fluids, however.

## BOLTED-FLANGE JOINTS 2.2.3

Flanges are expensive and for the most part are used to mate with flanged vessels, equipment, valves, and for process lines which may require periodic cleaning.

Flanged joints are made by bolting together two flanges with a gasket between them to provide a seal. Refer to 2.6 for standard forged-steel flanges and gaskets.

## FITTINGS 2.2.4

Fittings permit a change in direction of piping, a change in diameter of pipe, or a branch to be made from the main run of pipe. They are formed from plate or pipe, machined from forged blanks, cast, or molded from plastics.

Chart 2.1 shows the ratings of butt-welding fittings used with pipe of various schedule numbers and manufacturers' weights. For dimensions of butt-welding fittings and flanges, see tables D-1 thru D-6, and tables F-1 thru F-7. Drafting symbols are given in charts 5.3 thru 5.5.

Threaded fittings have Pressure Class designations of: 2000, 3000 and 6000. Socket-welding fittings have Pressure Class designations of: 3000, 6000 and 9000. How these Pressure Class designations relate to schedule numbers and manufacturers' weights for pipe is shown in table 2.2.

**CORRELATION OF CLASS OF THREADED & SOCKET-WELDING FITTINGS WITH SCHEDULES/WEIGHTS OF PIPE** **TABLE 2.2**

|                   | PIPE DESIGNATION SCH/MFR'S |       |      |      |
|-------------------|----------------------------|-------|------|------|
| Pressure Class    | 2000                       | 3000  | 6000 | 9000 |
| Threaded fittings | 80/XS                      | 160   | XXS  |      |
| Socketed fittings |                            | 80/XS | 160  | XXS  |

Sections 2.1.3 thru 2.2.4 have shown that there is a wide variety of differently-rated pipe, fittings and materials from which to make a choice. Charts 2.1 thru 2.3 show how various weights of pipe, fittings and valves can be combined in a piping system.

**COMPONENTS FOR BUTT-WELDED PIPING SYSTEMS** **2.3**

- WHERE USED:**
- For most process, utility and service piping
- ADVANTAGE OF JOINT:**
- Most practicable way of joining larger pipes and fittings which offers reliable, leakproof joints
- DISADVANTAGE OF JOINT:**
- Intruding weld metal may affect flow
- HOW JOINT IS MADE:**
- The end of the pipe is beveled as shown in chart 2.1. Fittings are similarly beveled by the manufacturer. The two parts are aligned, properly gapped, tack welded, and then a continuous weld is made to complete the joint

Chart 2.1 shows the ratings of pipe, fittings and valves that are commonly combined or may be used together. It is a guide only, and not a substitute for a project specification.

**FITTINGS, BENDS, MITERS & FLANGES** **2.3.1**  
**FOR BUTT-WELDED SYSTEMS**

Refer to tables D, F and W-1 for dimensions and weights of fittings and flanges.

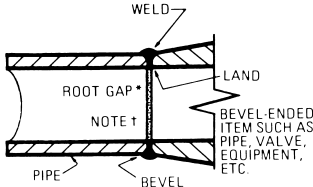


**ELBOWS** or '**ELLS**' make 90- or 45-degree changes in direction of the run of pipe. The elbows normally used are 'long radius' (LR) with centerline radius of curvature equal to 1½ times the nominal pipe size for NPS 3/4 and larger sizes. 'Short radius' (SR) elbows with centerline radius of curvature equal to the nominal pipe size are also available. 90-degree LR elbows with a straight extension at one end ('long tangent') are still available in STD weight, if required.

**REDUCING ELBOW** makes a 90-degree change in direction with change in line size. Reducing elbows have centerline radius of curvature 1½ times the nominal size of the pipe to be attached to the larger end.

**RETURN** changes direction of flow thru 180 degrees, and is used to construct heating coils, vents on tanks, etc.

**BENDS** are made from straight pipe. Common bending radii are 3 and 5 times the pipe size (3R and 5R bends, where R = nominal pipe size—nominal diameter, *not* radius). 3R bends are available from stock. Larger radius bends can be custom made, preferably by hot bending. Only seamless or electric-resistance-welded pipe is suitable for bending.

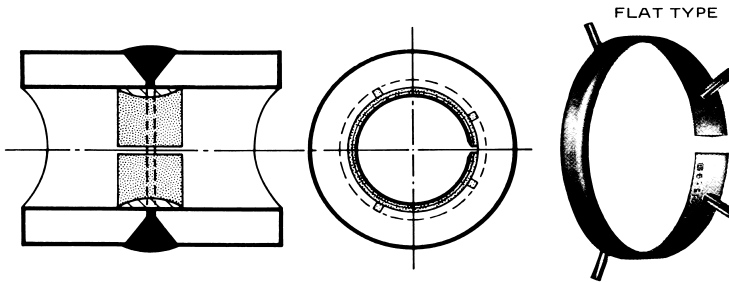
| BUTT-WELDED PIPING   |   | CHART 2.1   |  |  |
|--|---|---|--|--|
| CARBON-STEEL PIPE & FORGED-STEEL FITTINGS  |   |   |  |  |
| END PREPARATION OF PIPE, & METHOD OF JOINING TO BEVEL-ENDED PIPE, FITTING, FLANGE, VALVE, OR EQUIPMENT   |  |   |  |  |
| MINIMUM LINE SIZE NORMALLY BUTT-WELDED   | NPS 2   |   |  |  |
| WEIGHT OF PIPE & FITTINGS NORMALLY USED. CHOICE OF OTHER MATERIALS OR HEAVIER-WEIGHT PIPE & FITTINGS WILL DEPEND ON PRESSURE, TEMPERATURE &/OR THE CORROSION ALLOWANCE REQUIRED. NPS 2 AND LARGER PIPE IS USUALLY ORDERED TO ASTM A-53, Grade B. SEE 2.1.4, UNDER 'STEELS' | FOR NOMINAL PIPE SIZE:  | NPS 2 to NPS 6  | NPS 8 and larger<br>CALCULATE WALL THICKNESS FROM CODE |  |
|  | SCHEDULE NUMBER   | SCH 40  | SCH 20 or SCH 30                                       |  |
|  | MFRS' WEIGHT  | STD   | —  |  |
| VALVES   |   |   |  |  |
| PRESSURE RATING CLASS  | FOR NPS 2 AND LARGER VALVES   | 150, 300, 600, 900 AND HIGHER<br>ACCORDING TO SYSTEM PRESSURE |  |  |
|  | FOR NPS 1½ AND SMALLER VALVES   | SEE CHARTS 2.2 AND 2.3  |  |  |
|  | FOR CONTROL VALVES  | USUALLY 300 MINIMUM (SEE 3.1.10)                              |  |  |

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\*See 5.3.5 under 'Dimensioning spools'  
†A 'backing ring'—sometimes termed a 'chill ring'—may be inserted between any butt-welding joint prior to welding. Preventing weld spatter and spikes ('icicles') of weld metal from forming inside the pipe during welding, the ring also serves as an alignment aid. Normally used for severe service, but should be considered for process fluids such as fibrous suspensions, where weld icicles could result in material collecting at joints and choking lines. See 2.11

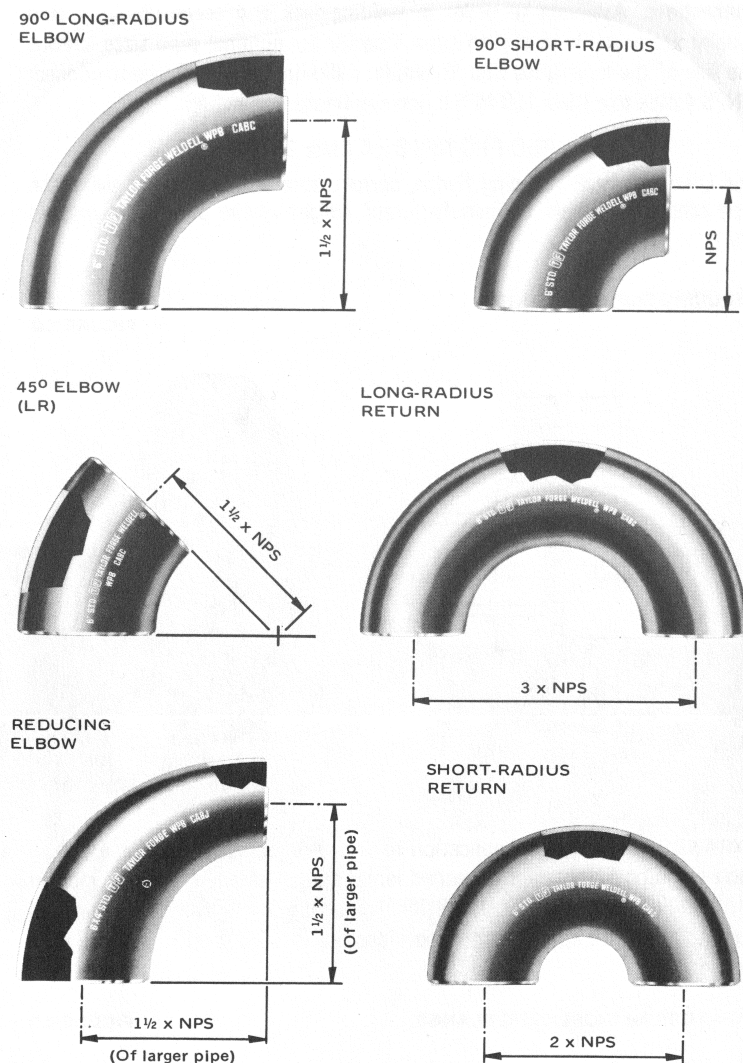
**BACKING RING**

**FIGURE 2.1**



## ELBOWS & RETURNS

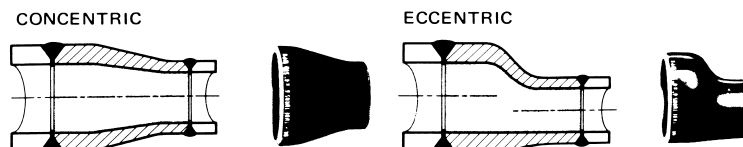
FIGURE 2.2



**REDUCER (or INCREASER)** joins a larger pipe to a smaller one. The two available types, concentric and eccentric, are shown. The eccentric reducer is used when it is necessary to keep either the top or the bottom of the line level—offset equals  $\frac{1}{2} \times (\text{larger ID minus smaller ID})$ .

## REDUCERS

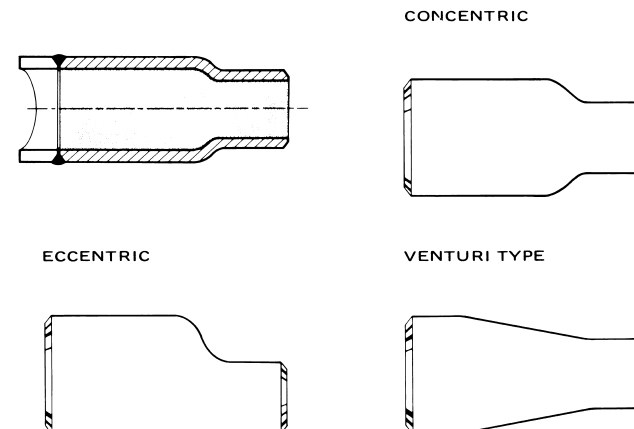
FIGURE 2.3



**SWAGE** is employed to connect butt-welded piping to smaller screwed or socket-welded piping. In butt-welded lines, used as an alternative to the reducer when greater reductions in line size are required. Regular swages in concentric or eccentric form give abrupt change of line size, as do reducers. The 'venturi' swage allows smoother flow. Refer to table 2.3 for specifying swages for joining to socket-welding items, and to table 2.4 for specifying swages for joining to screwed piping. For offset, see 'Reducer'.

## SWAGES, or SWAGED NIPPLES

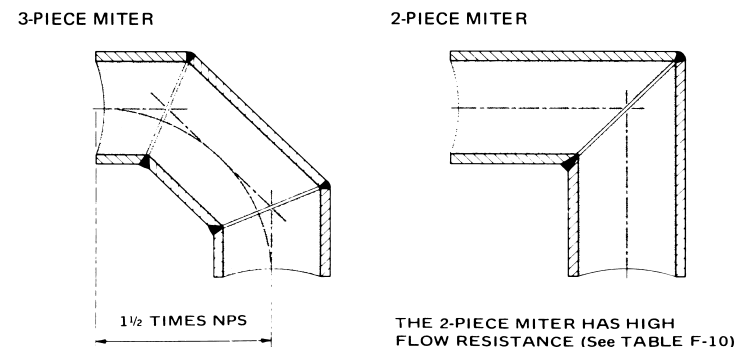
FIGURE 2.4



**MITERED ELBOWS** are fabricated as required from pipe—they are not fittings. The use of miters to make changes in direction is practically restricted to low-pressure lines 10-inch and larger if the pressure drop is unimportant; for these uses regular elbows would be costlier. A 2-piece, 90-degree miter has four to six times the hydraulic resistance of the corresponding regular long-radius elbow, and should be used with caution. A 3-piece 90-degree miter has about double the resistance to flow of the regular long-radius elbow—refer to table F-10. Constructions for 3-, 4-, and 5-piece miters are shown in tables M-2.

## 3-PIECE & 2-PIECE MITERS

FIGURE 2.5

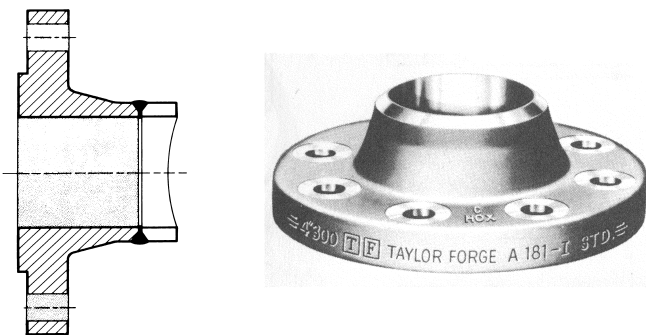


The following five flange types are used for butt-welded lines. The different flange facings available are discussed in 2.6.

**WELDING-NECK FLANGE, REGULAR & LONG** *Regular welding-neck flanges are used with butt-welding fittings.* Long welding-neck flanges are primarily used for vessel and equipment nozzles, rarely for pipe. Suitable where extreme temperature, shear, impact and vibratory stresses apply. Regularity of the bore is maintained. Refer to tables F for bore diameters of these flanges.

**WELDING-NECK FLANGE**

**FIGURE 2.6**



**SLIP-ON FLANGE** is properly used to flange pipe. Slip-on flanges can be used with long-tangent elbows, reducers, and swages (not usual practice). The internal weld is slightly more subject to corrosion than the butt weld. The flange has poor resistance to shock and vibration. It introduces irregularity in the bore. It is cheaper to buy than the welding-neck flange, but is costlier to assemble. It is easier to align than the welding-neck flange. Calculated strengths under internal pressure are about one third that of the corresponding welding-neck flanges. The pipe or fitting is set back from the face of the flange a distance equal to the wall thickness  $-0'' + 1/16''$ .

**SLIP-ON FLANGE**

**FIGURE 2.7**



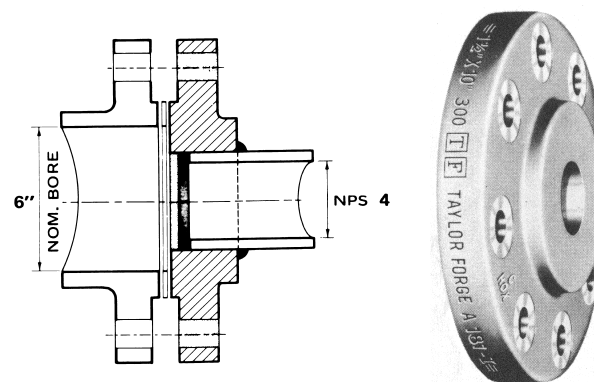
**REDUCING FLANGE** Suitable for changing line size, but should not be used if abrupt transition would create undesirable turbulence, as at pump connections. Available to order in welding-neck and eccentric types, and usually from stock in slip-on type. Specify by nominal pipe sizes, stating the size of the larger pipe first. Example: a slip-on reducing flange to connect a NPS 4 pipe to a Class 150 NPS 6 line-size flange is specified:

RED FLG NPS 6 x 4 Class 150 SO

For a welding-neck reducing flange, correct bore is obtained by giving the pipe schedule number or manufacturers' weight of the pipe to be welded on.

**REDUCING SLIP-ON FLANGE**

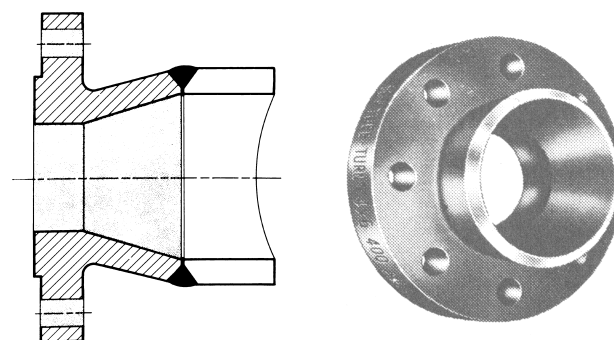
**FIGURE 2.8**



**EXPANDER FLANGE** Application as for welding-neck flange—see above. Increases pipe size to first or second larger size. Alternative to using reducer and welding-neck flange. Useful for connecting to valves, compressors and pumps. Pressure ratings and dimensions are in accord with ANSI B16.5.

**EXPANDER (or INCREASER) FLANGE**

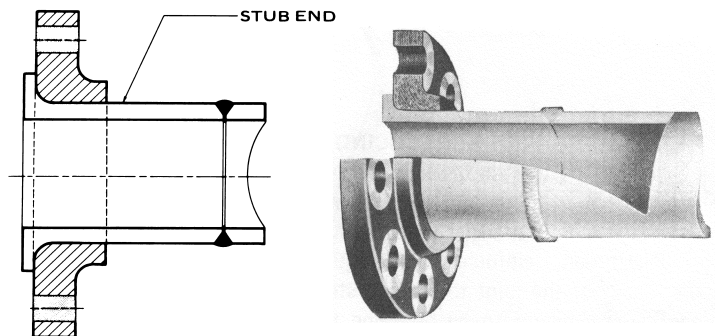
**FIGURE 2.9**



**LAP-JOINT, or 'VAN STONE', FLANGE** Economical if costly pipe such as stainless steel is used, as the flange can be of carbon steel and only the lap-joint stub end need be of the line material. A stub end must be used in a lap joint, and the cost of the two items must be considered. If both stub and flange are of the same material they will be more expensive than a welding-neck flange. Useful where alignment of bolt holes is difficult, as with spools to be attached to flanged nozzles of vessels.

**LAP-JOINT FLANGE (with Stub-end)**

**FIGURE 2.10**



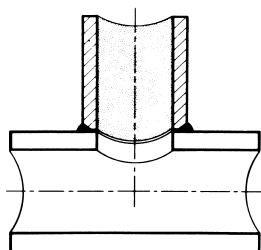
### BUTT-WELDING FITTINGS FOR BRANCHING FROM BUTT-WELDED SYSTEMS

2.3.2

**STUB-IN** Term for a branch pipe welded directly into the side of the main pipe run—it is not a fitting. This is the commonest and least expensive method of welding a full-size or reducing branch for pipe 2-inch and larger. A stub-in can be reinforced by means set out in 2.11.

#### STUB-IN

**FIGURE 2.11**



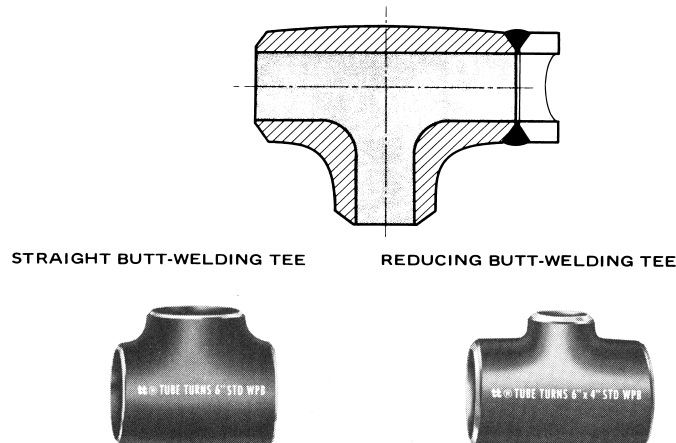
**BUTT-WELDING TEES, STRAIGHT or REDUCING**, are employed to make 90-degree branches from the main run of pipe. Straight tees, with branch the same size as the run, are readily available. Reducing tees have branch smaller than the run. Bullhead tees have branch larger than the run, and are very seldom used but can be made to special order. None of these tees requires reinforcement. Reducing tees are ordered as follows:—

### SPECIFYING SIZE OF BUTT-WELDING REDUCING TEES

| HOW TO SPECIFY TEES: | RUN INLET | RUN OUTLET | BRANCH | EXAMPLE           |
|----------------------|-----------|------------|--------|-------------------|
| REDUCING ON BRANCH   | 6"        | 6"         | 4"     | RED TEE 6 x 6 x 4 |

#### BUTT-WELDING TEES

**FIGURE 2.12**

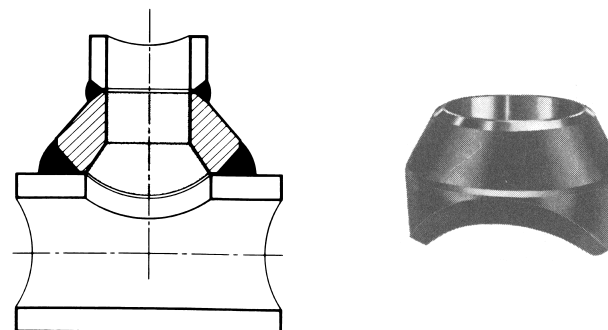


The next four branching fittings are made by Bonney Forge. These fittings offer an alternate means of connecting into the main run, and do not require reinforcement. They are preshaped to the curvature of the run pipe.

**WELDOLET** makes a 90-degree branch, full-size or reducing, on straight pipe. Closer manifolding is possible than with tees. Flat-based weldolets are available for connecting to pipe caps and vessel heads.

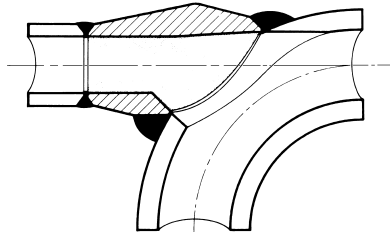
#### WELDOLET

**FIGURE 2.13**

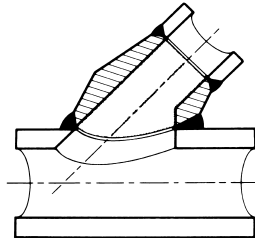


**BUTT-WELDING ELBOLET** makes a reducing tangent branch on long-radius and short-radius elbows.

**ELBOLET**  
**FIGURE 2.14**



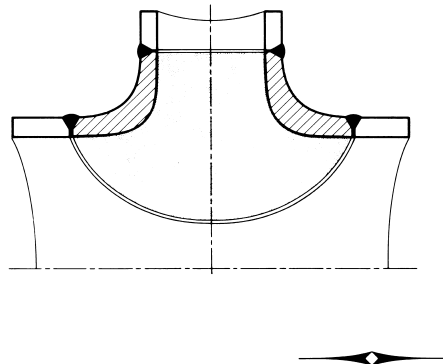
**BUTT-WELDING LATROLET**  
**FIGURE 2.15**



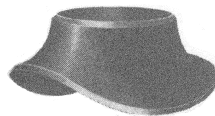
**BUTT-WELDING LATROLET** makes a 45-degree reducing branch on straight pipe.

**SWEEPOLET** makes a 90-degree reducing branch from the main run of pipe. Primarily developed for high-yield pipe used in oil and gas transmission lines. Provides good flow pattern, and optimum stress distribution.

**SWEEPOLET**



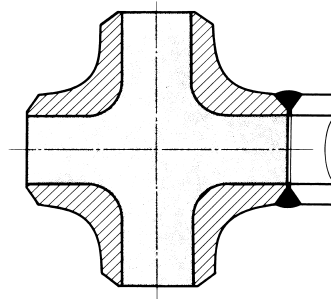
**FIGURE 2.16**



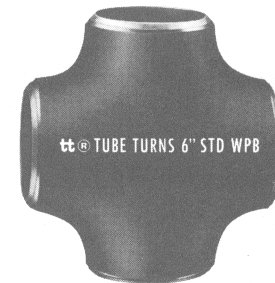
The next three fittings are usually used for special designs:

**CROSS, STRAIGHT or REDUCING** Straight crosses are usually stock items. Reducing crosses may not be readily available. For economy, availability and to minimize the number of items in inventory, it is preferred to use tees, etc., and not crosses, except where space is restricted, as in marine piping or 're-vamp' work. Reinforcement is not needed.

**BUTT-WELDING CROSS**



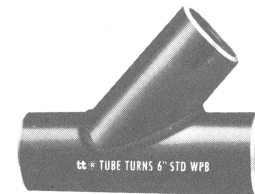
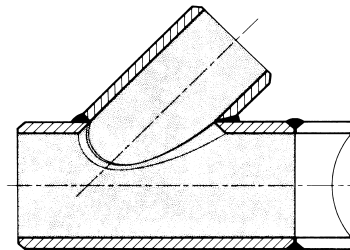
**FIGURE 2.17**



**LATERAL, STRAIGHT or REDUCING**, permits odd-angled entry into the pipe run where low resistance to flow is important. Straight laterals with branch bore equal to run bore are available in STD and XS weights. Reducing laterals and laterals at angles other than 45 degrees are usually available only to special order. Reinforcement is required where it is necessary to restore the strength of the joint to the full strength of the pipe. Reducing laterals are ordered similarly to butt-welding tees, except that the angle between branch and run is also stated.

**LATERAL**

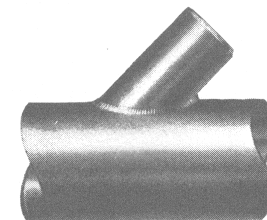
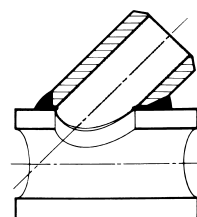
**FIGURE 2.18**



**SHAPED NIPPLE** Now rarely used, but can be obtained from stock in 90- and 45-degree angles, and in any size and angle, including offset, to special order. The run is field-cut, using the nipple as template. Needs reinforcement if it is necessary to bring the strength of the joint up to the full strength of the pipe.

**SHAPED NIPPLE**

**FIGURE 2.19**



## CLOSURES

2.3.3

**CAP** is used to seal the end of pipe. (See figure 2.20(a).)

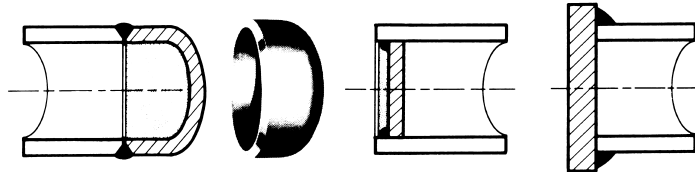
**FLAT CLOSURES** Flat plates are normally cut especially from plate stock by the fabricator or erector. (See figure 2.20 (b) and (c).)

### THREE WELDED CLOSURES

FIGURE 2.20

(a) BUTT-WELDING CAP

(b) FLAT CLOSURE (c) FLAT CLOSURE



**ELLIPSOIDAL, or DISHED, HEADS** are used to close pipes of large diameter, and are similar to those used for constructing vessels.

## COMPONENTS FOR SOCKET-WELDED PIPING SYSTEMS

2.4

### WHERE USED:

For lines conveying flammable, toxic, or expensive material, where no leakage can be permitted. For steam: 300 to 600 PSI, and sometimes 150 PSI steam. For corrosive conditions, see Index under 'Corrosion'

### ADVANTAGES OF JOINT:

- (1) Easier alignment on small lines than butt welding. Tack welding is unnecessary
- (2) No weld metal can enter bore
- (3) Joint will not leak, when properly made

### DISADVANTAGES OF JOINT:

- (1) The 1/16-inch recess in joint (see chart 2.2) pockets liquid
- (2) Use not permitted by ANSI B31.1 - 1989 if severe vibration or crevice corrosion is anticipated

### HOW JOINT IS MADE:

The end of the pipe is finished flat, as shown in chart 2.2. It is located in the fitting, valve, flange, etc., and a continuous fillet weld is made around the circumference

## SOCKET-WELDED PIPING

CHART 2.2

Chart 2.2 shows the ratings of pipe, fittings and valves that are commonly combined, or may be used together. The chart is a guide only, and not a substitute for a project specification.

| SOCKET-WELDED PIPING  |                                  |                   | CHART 2.2                                |         |      |
|---|----------------------------------|-------------------|--|---------|------|
| CARBON-STEEL PIPE & FORGED-STEEL FITTINGS   |                                  |                   |  |         |      |
| END PREPARATION OF PIPE, AND METHOD OF JOINING TO FITTING, FLANGE, VALVE, OR EQUIPMENT  |                                  |                   |  |         |      |
|   |                                  |                   | MAXIMUM LINE SIZE NORMALLY SOCKET WELDED |         |      |
| AVAILABILITY OF FORGED-STEEL SOCKET-WELDING FITTINGS  |                                  |                   | NPS 1/8 to NPS 4                         |         |      |
| WEIGHTS OF PIPE AND PRESSURE CLASSES OF FITTINGS WHICH ARE COMPATIBLE   | PIPE                             | SCHEDULE NUMBER   | SCH 80                                   | SCH 160 | —    |
|   |                                  | MFRS' WEIGHT      | XS                                       | —       | XXS  |
|   | FITTINGS                         | FITTING CLASS     | 3000                                     | 6000    | 9000 |
|   |                                  | FITTING BORED TO: | SCH 40                                   | SCH 160 | XXS  |
| <div>↑</div> <div>MOST COMMON COMBINATION: CHOICE OF MATERIAL OR HEAVIER-WEIGHT PIPE AND FITTING WILL DEPEND ON PRESSURE, TEMPERATURE AND/OR CORROSION ALLOWANCE REQUIRED. PIPE NPS 1½ AND SMALLER IS USUALLY ORDERED TO ASTM SPECIFICATION A-106 Grade B. REFER TO 2.1.4, UNDER 'STEELS'</div> |                                  |                   |  |         |      |
| VALVES  |                                  |                   |  |         |      |
| MINIMUM PRESSURE (RATING) CLASS   | CONTROL VALVES (USUALLY FLANGED) |                   | USUALLY 300 (SEE 3.1.10)                 |         |      |
|   | VALVES OTHER THAN CONTROL VALVES |                   | 600 (ANSI)<br>800 (API)                  |         |      |

\* ANSI B16.11 recommends a 1/16th-inch gap to prevent weld from cracking under thermal stress

† Socket-ended fittings are now only made in classes 3000 6000 and 9000 (ANSI B16.11)

## FITTINGS & FLANGES FOR SOCKET-WELDED SYSTEMS

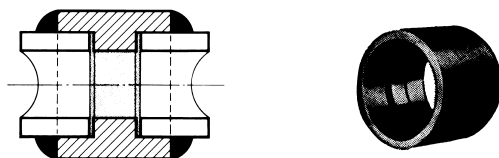
2.4.1

Dimensions of fittings and flanges are given in tables D-8 and F-1 thru F-6.

**FULL-COUPLING** (termed 'COUPLING') joins pipe to pipe, or to a nipple, swage, etc.

**FULL-COUPLING**

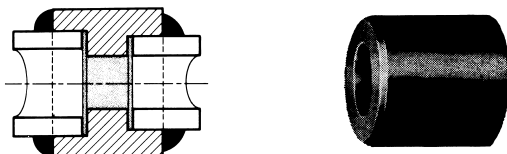
FIGURE 2.21



**REDUCER** joins two different diameters of pipe.

**REDUCER**

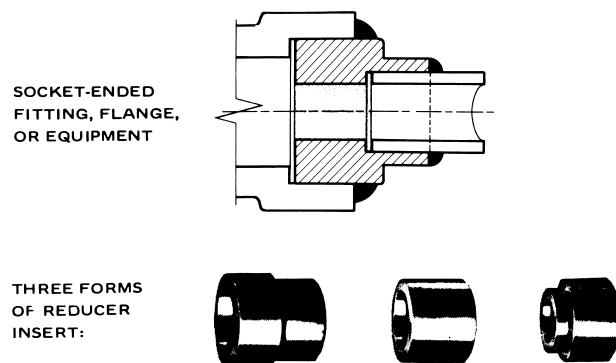
FIGURE 2.22



**REDUCER INSERT** A reducing fitting used for connecting a small pipe to a larger fitting. Socket-ended reducer inserts can be made in any reduction by boring standard forged blanks.

**SOCKET-WELDING REDUCING INSERTS**

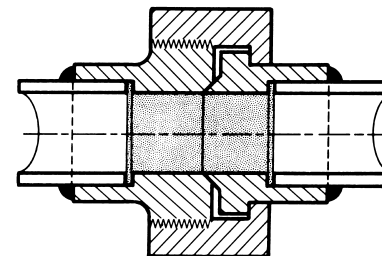
FIGURE 2.23



**UNION** is used primarily for maintenance and installation purposes. This is a screwed joint designed for use with socket-welded piping systems. See explanation in 2.5.1 of uses given under 'threaded union'. Union should be screwed tight before the ends are welded, to minimize warping of the seat.

**SOCKET-WELDING UNION**

FIGURE 2.24



**SWAGED NIPPLES** According to type, these allow joining: (1) Socket-ended items of different sizes—this type of swaged nipple has both ends plain (PBE) for insertion into socket ends. (2) A socket-ended item to a larger butt-welding pipe or fitting—this type of swaged nipple has the larger end beveled (BLE) and the smaller end plain (PSE) for insertion into a socket-ended item. A swaged nipple is also referred to as a 'swage' (pronounced 'swedge') abbreviated on drawings as 'SWG' or 'SWG NIPP'. When ordering a swage, state the weight designations of the pipes to be joined. For example, NPS 2 (SCH 40) x NPS 1 (SCH 80). Examples of the different end terminations that may be specified are as follows:-

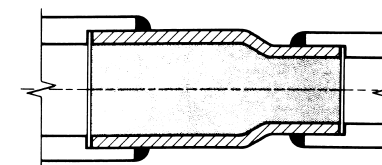
**SPECIFYING SIZE & END FINISH  
OF SOCKET-WELDING SWAGES**

TABLE 2.3

| SWAGE FOR JOINING —<br>LARGER to SMALLER |         | EXAMPLE NOTE ON DRAWING  |
|--|---------|--|
| SW ITEM                                  | SW ITEM | SWG 1½ x 1 PBE   |
| BW FITTING or PIPE                       | SW ITEM | SWG 2 x 1 BLE-PSE  |
| ABBREVIATIONS:                           |         | SW = Socket welding    BW = Butt welding<br>PBE = Plain both ends    BLE = Bevel large end<br>PSE = Plain small end    BLE = Bevel large end |

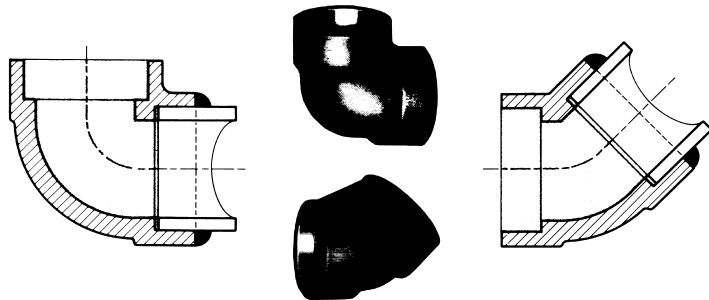
**SWAGE (PBE)**

FIGURE 2.25



**ELBOWS** make 90- or 45-degree changes of direction in the run of pipe.  
**SOCKET-WELDING ELBOWS**

**FIGURE 2.26**

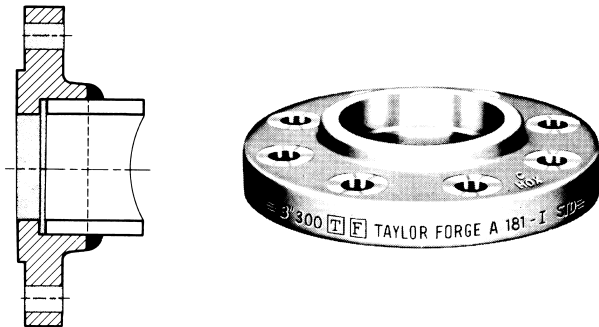


**SOCKET-WELDING FLANGE** Regular type is available from stock. Reducing type is available to order. For example, a reducing flange to connect a NPS 1 pipe to a Class 150 NPS 1½ line-size flange is specified:

RED FLG NPS 1½ x 1 Class 150 SW

**SOCKET-WELDING FLANGE**

**FIGURE 2.27**



## FITTINGS FOR BRANCHING FROM SOCKET-WELDED SYSTEMS

### 2.4.2

#### BRANCH FROM SOCKET-WELDED RUN

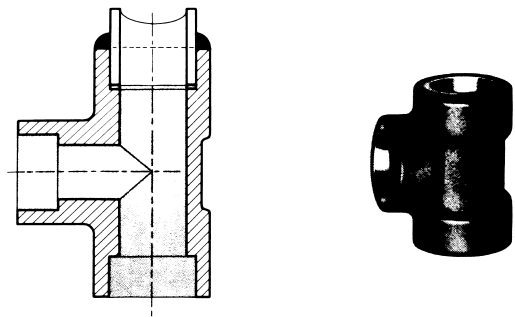
**TEE, STRAIGHT or REDUCING**, makes 90-degree branch from the main run of pipe. Reducing tees are custom-fabricated by boring standard forged blanks.

#### SPECIFYING SIZE OF SOCKET-WELDING TEES

| HOW TO SPECIFY TEES:                           | RUN INLET | RUN OUTLET | BRANCH | EXAMPLE                   |
|--|-----------|------------|--------|---------------------------|
| REDUCING ON BRANCH                             | 1 1/2"    | 1 1/2"     | 1"     | RED TEE 1 1/2 x 1 1/2 x 1 |
| REDUCING ON RUN<br>(SPECIAL APPLICATIONS ONLY) | 1 1/2"    | 1"         | 1 1/2" | RED TEE 1 1/2 x 1 x 1 1/2 |

## SOCKET-WELDING TEE

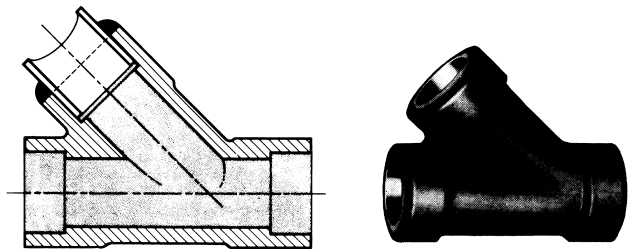
**FIGURE 2.28**



**LATERAL** makes full-size 45-degree branch from the main run of pipe.

**SOCKET-WELDING LATERAL**

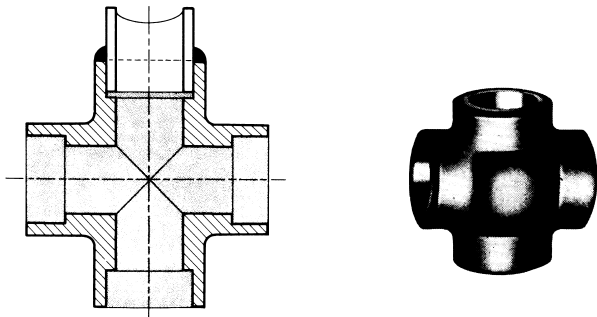
**FIGURE 2.29**



**CROSS** Remarks for butt-welding cross apply—see 2.3.2. Reducing crosses are custom-fabricated by boring standard forged blanks.

**SOCKET-WELDING CROSS**

**FIGURE 2.30**



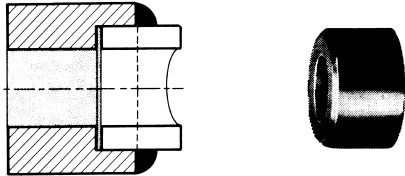
## FITTINGS FOR SOCKET-WELDED BRANCH FROM VESSEL OR BUTT-WELDED MAIN RUN

2.4.3

**HALF-COUPLING** The full-coupling is not used for branching or for vessel connections, as the half-coupling is the same length and is stronger. The half-coupling permits 90-degree entry into a larger pipe or vessel wall. The sockolet is more practicable as shaping is necessary with the coupling.

### SOCKET-WELDING HALF-COUPLING

FIGURE 2.31

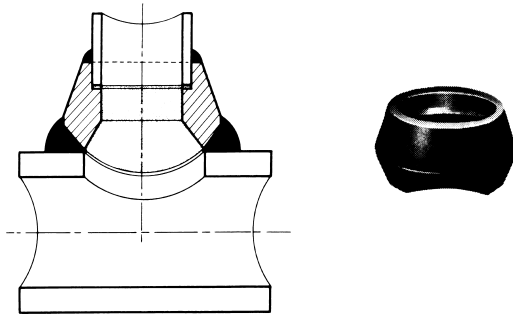


The next four fittings are made by Bonney Forge and offer an alternate method of entering the main pipe run. They have the advantage that the beveled welding ends are shaped to the curvature of the run pipe. Reinforcement for the butt-welded piping or vessel is not required.

**SOCKOLET** makes a 90-degree branch, full-size or reducing, on straight pipe. Flat-based sockolets are available for branch connections on pipe caps and vessel heads.

### SOCKOLET

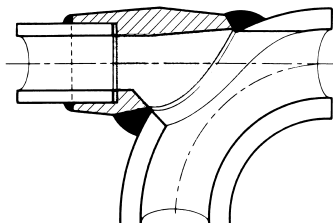
FIGURE 2.32



**SOCKET-WELDING ELBOLET** makes a reducing tangent branch on long-radius and short-radius elbows.

### SOCKET-WELDING ELBOLET

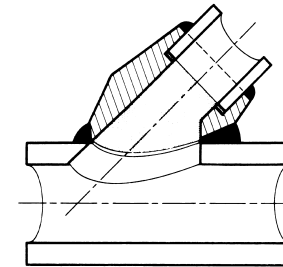
FIGURE 2.33



**SOCKET-WELDING LATROLET** makes a 45-degree reducing branch on straight pipe.

### SOCKET-WELDING LATROLET

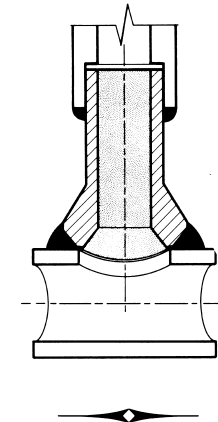
FIGURE 2.34



**NIPOLET** A variant of the sockolet, having integral plain nipple. Primarily developed for small valved connections—see figure 6.47.

### NIPOLET

FIGURE 2.35



**STUB-IN** See comments in 2.3.2. Not preferred for lines under 2-inch due to risk of weld metal entering line and restricting flow.

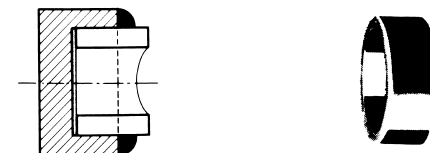
### CLOSURE

2.4.4

**SOCKET-WELDING CAP** seals plain-ended pipe.

### SOCKET-WELDING CAP

FIGURE 2.36



## COMPONENTS FOR SCREWED PIPING SYSTEMS

2.5

**WHERE USED:** For lines conveying services, and for smaller process piping

**ADVANTAGES:**

- (1) Easily made from pipe and fittings on site
- (2) Minimizes fire hazard when installing piping in areas where flammable gases or liquids are present

**DISADVANTAGES:**

- (1)\* Use not permitted by ANSI B31.1-1989, if severe erosion, crevice corrosion, shock, or vibration is anticipated, nor at temperatures over 925 F. (Also see footnote table F-9)
- (2) Possible leakage of joint
- (3)\* Seal welding may be required—see footnote to chart 2.3
- (4) Strength of the pipe is reduced, as forming the screwthread reduces the wall thickness

\*These remarks apply to systems using forged-steel fittings.

### FITTINGS & FLANGES FOR SCREWED SYSTEMS

2.5.1

Screwed piping is piping assembled from threaded pipe and fittings.

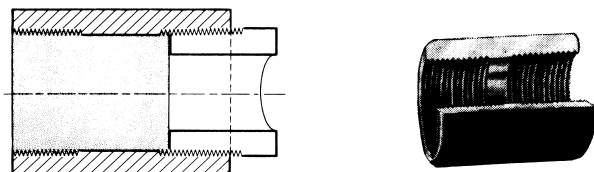
Threaded malleable-iron and cast-iron fittings are extensively used for plumbing in buildings. In industrial applications, Class 150 and 300 galvanized malleable-iron fittings and similarly rated valves are used for drinking water and air lines. Dimensions of malleable-iron fittings are given in table D-11.

In process piping, forged-steel fittings are preferred over cast-iron and malleable-iron fittings (although their pressure/temperature ratings may be suitable), for their greater mechanical strength. To simplify material specifications, drafting, checking, purchasing and warehousing, the overall economics are in favor of utilizing as few different types of threaded fittings as possible. Dimensions of forged-steel threaded fittings are given in table D-9.

**FULL-COUPLING (termed 'COUPLING')** joins pipe or items with threaded ends.

**FULL-COUPLING**

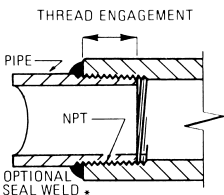

**FIGURE 2.37**



## SCREWED PIPING

CHART 2.3

Chart 2.3 shows the ratings of pipe, fittings and valves that are commonly combined, or may be used together. The chart is a guide only, and not a substitute for a project specification.

| SCREWED PIPING   |                                  |                 | CHART 2.3   |        |      |
|--|----------------------------------|-----------------|---|--------|------|
| CARBON-STEEL PIPE & FORGED-STEEL FITTINGS  |                                  |                 |   |        |      |
| END PREPARATION OF PIPE, AND METHOD OF JOINING TO FITTING, FLANGE, VALVE OR EQUIPMENT  |                                  |                 |  |        |      |
| MAXIMUM LINE SIZE NORMALLY THREADED  |                                  |                 | NPS 1½  |        |      |
| AVAILABILITY OF FORGED-STEEL THREADED FITTINGS   |                                  |                 | NPS 1/8 to NPS 4  |        |      |
| WEIGHTS OF PIPE AND PRESSURE CLASSES OF FITTINGS WHICH ARE COMPATIBLE  | PIPE                             | SCHEDULE NUMBER | SCH 40  | SCH 80 | —    |
|  |                                  | MFRS' WEIGHT    | STD   | XS     | XXS  |
|  | FITTING CLASS                    |                 | 2000  | 3000   | 6000 |
|  <div>MOST COMMON COMBINATION: THE MINIMUM CLASS FOR FITTINGS PREFERRED IN MOST INSTANCES FOR MECHANICAL STRENGTH IS 3000. CHOICE OF MATERIAL OR HEAVIER-WEIGHT PIPE &amp; FITTING WILL DEPEND ON PRESSURE, TEMPERATURE AND /OR CORROSION ALLOWANCE REQUIRED. PIPE NPS 1½ AND SMALLER IS USUALLY ORDERED TO ASTM SPECIFICATION A-106 Grade B. REFER TO 2.1.4, UNDER 'STEELS'</div> |                                  |                 |   |        |      |
| VALVES   |                                  |                 |   |        |      |
| MINIMUM PRESSURE (RATING) CLASS  | CONTROL VALVES (USUALLY FLANGED) |                 | USUALLY 300 (SEE 3.1.10)  |        |      |
|  | VALVES OTHER THAN CONTROL VALVES |                 | 600 (ANSI)<br>800 (API)   |        |      |

\* ANSI B31.1.0 states that seal welding shall not be considered to contribute to the strength of the joint

#### SEAL WELDING APPLICATIONS

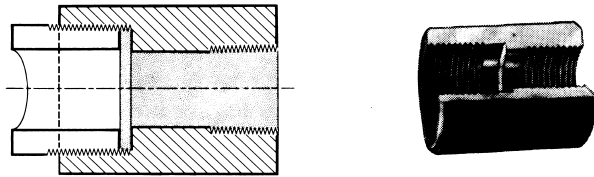
**On-plot:** On all screwed connections within battery limits, with the exception of piping carrying air or other inert gas, and water

**Off-plot:** On screwed lines for hydrocarbon service and for lines conveying dangerous, toxic, corrosive or valuable fluids

**REDUCING COUPLING, or REDUCER,** joins threaded pipes of different sizes. Can be made in any reduction by boring and tapping standard forged blanks.

**REDUCING COUPLING**

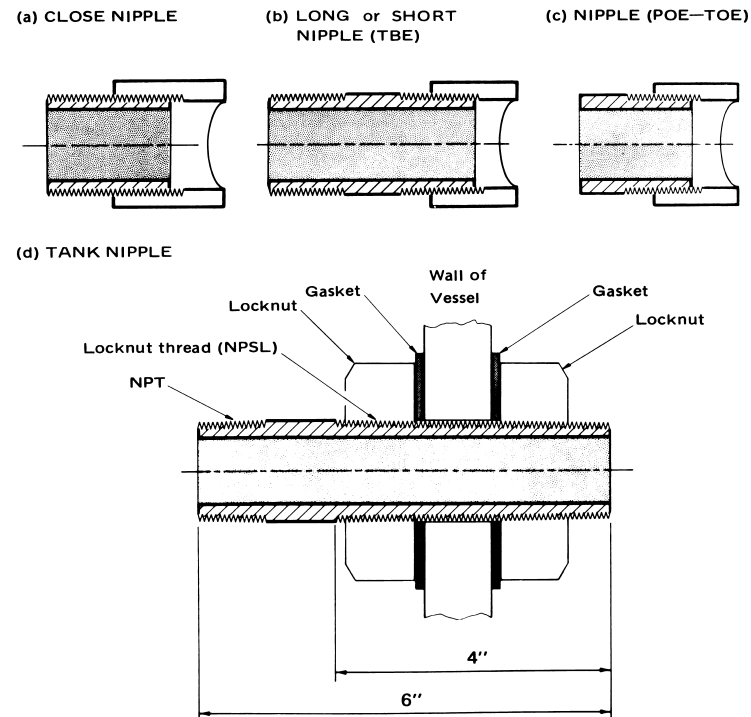
**FIGURE 2.38**



**NIPPLES** join unions, valves, strainers, fittings, etc. Basically a short length of pipe either fully threaded (close nipple) or threaded both ends (TBE), or plain one end and threaded one end (POE—TOE). Available in various lengths -refer to table D-11. Nipples can be obtained with a Victaulic groove at one end.

**NIPPLES FOR THREADED ITEMS**

**FIGURE 2.39**

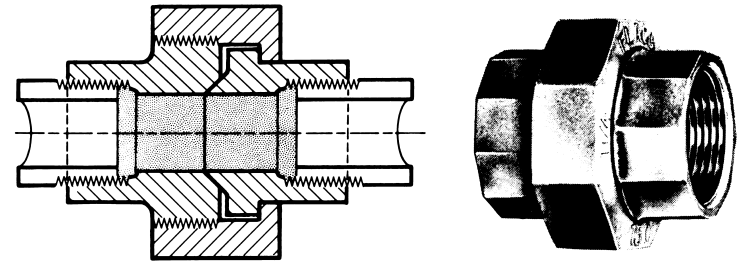


**TANK NIPPLE** is used for making a screwed connection to a non-pressure vessel or tank in low-pressure service. Overall length is usually 6 inches with a standard taper pipe thread at each end. On one end only, the taper pipe thread runs into a ANSI lock-nut thread.

**UNION** makes a joint which permits easy installation, removal or replacement of lengths of pipe, valves or vessels in screwed piping systems. Examples: to remove a valve it must have at least one adjacent union, and to remove piping from a vessel with threaded connections, each outlet from the vessel should have one union between valve and vessel. Ground-faced joints are preferred, although other facings are available.

**THREADED UNION**

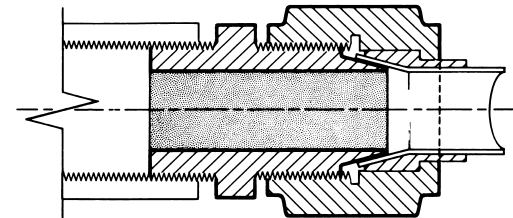
**FIGURE 2.40**



**PIPE-TO-TUBE CONNECTOR** For joining threaded pipe to tube. Figure 2.41 shows a connector fitted to specially-flared tube. Other types are available.

**PIPE-TO-TUBE CONNECTOR**

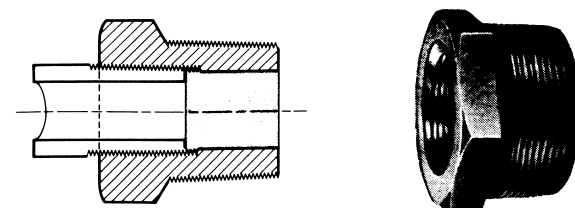
**FIGURE 2.41**



**HEXAGON BUSHING** A reducing fitting used for connecting a smaller pipe into a larger threaded fitting or nozzle. Has many applications to instrument connections. Reducing fittings can be made in any reduction by boring and tapping standard forged blanks. Normally not used for high-pressure service.

**HEXAGON BUSHING**

**FIGURE 2.42**



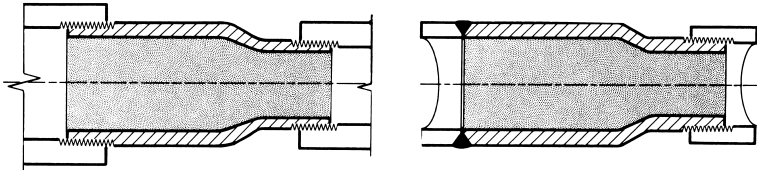
**SWAGED NIPPLE** This is a reducing fitting, used for joining larger diameter to smaller diameter pipe. Also referred to as a 'swage (pronounced 'swedge') and abbreviated as 'SWG' or 'SWG NIPP' on drawings. When ordering a swage, state the weight designations of the pipes to be joined: for example, NPS 2 (SCH 40) x NPS 1 (SCH 80). A swage may be used for joining: (1) Screwed piping to screwed piping. (2) Screwed piping to butt-welded piping. (3) Butt-welded piping to a threaded nozzle on equipment. It is necessary to specify on the piping drawing the terminations required.

SPECIFYING SIZE & END FINISH OF THREADED SWAGES TABLE 2.4

| SWAGE FOR JOINING——<br>LARGER to SMALLER  |           | EXAMPLE NOTE ON DRAWING  |
|---|-----------|--|
| THRD ITEM   | THRD ITEM | SWG 1½ x 1 TBE   |
| BW ITEM or PIPE   | THRD ITEM | SWG 2 x 1 BLE–TSE  |
| THRD ITEM*  | BW ITEM*  | SWG 3 x 2 TLE–BSE  |
| ABBREVIATIONS: BW = Butt welding<br>THRD = Threaded<br>TBE = Threaded both ends<br>TSE = Threaded small end |           | TLE = Threaded large end<br>TOE = Threaded one end<br>BLE = Beveled large end<br>BSE = Beveled small end |

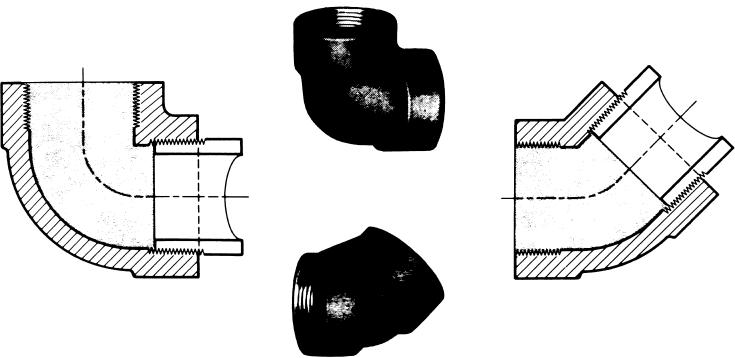
\* A larger threaded item is seldom joined to a smaller buttwelding item. However, the connection of a buttwelded line to a threaded nozzle on a vessel is an example.

SWAGED NIPPLES, TBE and BLE–TSE FIGURE 2.43



**ELBOWS** make 90- or 45-degree changes in direction of the run of pipe. Street elbows having an integral nipple at one end (see table D-11), are available

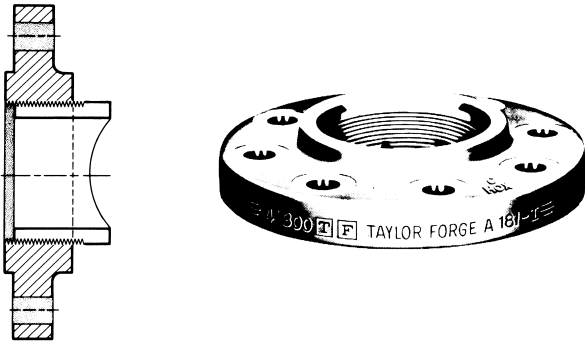
THREADED ELBOWS, 45 and 90 DEGREE FIGURE 2.44



**THREADED FLANGES** are used to connect threaded pipe to flanged items. Regular and reducing types are available from stock. For example, a reducing flange to connect a NPS 1 pipe to a Class 150 NPS 1½ line-size flange is specified:

RED FLG NPS 1½ x 1 Class 150 THRD

THREADED FLANGE FIGURE 2.45



FITTINGS FOR BRANCHING FROM SCREWED SYSTEMS 2.5.2

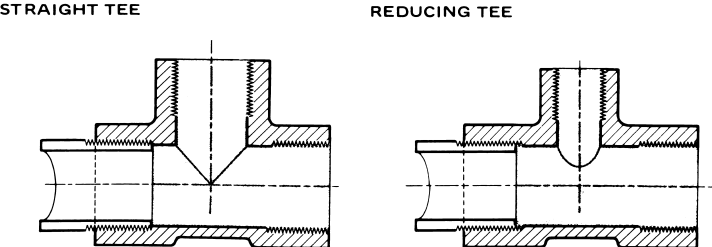
BRANCH FROM SCREWED MAIN RUN

**TEE, STRAIGHT or REDUCING**, makes a 90-degree branch from the run of pipe. Reducing tees are made by boring and tapping standard forged blanks.

SPECIFYING SIZE OF THREADED REDUCING TEES

| HOW TO SPECIFY TEES:                           | RUN INLET | RUN OUTLET | BRANCH | EXAMPLE             |
|--|-----------|------------|--------|---------------------|
| REDUCING ON BRANCH                             | 1½"       | 1½"        | 1"     | RED TEE 1½ x 1½ x 1 |
| REDUCING ON RUN<br>(SPECIAL APPLICATIONS ONLY) | 1½"       | 1"         | 1½"    | RED TEE 1½ x 1 x 1½ |

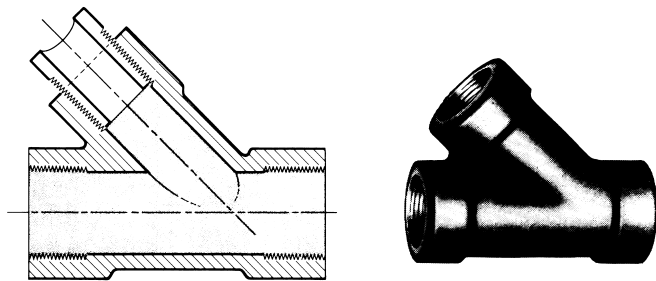
THREADED TEES, STRAIGHT and REDUCING FIGURE 2.46



**LATERAL** makes full-size 45-degree branch from the main run of pipe.

**THREADED LATERAL**

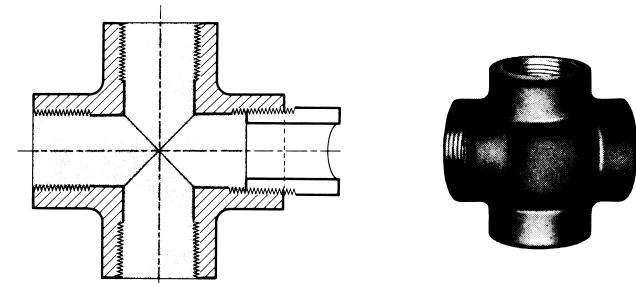
**FIGURE 2.47**



**CROSS** Remarks for butt-welding cross apply – see 2.3.2. Reducing crosses are made by boring and tapping standard forged blanks.

**THREADED CROSS**

**FIGURE 2.48**



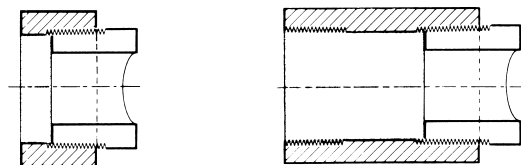
**FITTINGS FOR SCREWED BRANCH FROM VESSEL OR BUTT-WELDED MAIN RUN**

**2.5.3**

**HALF-COUPLING** can be used to make 90-degree threaded connections to pipes for instruments, or for vessel nozzles. Welding heat may cause embrittlement of the threads of this short fitting. Requires shaping.

**THREADED HALF-COUPLING & FULL-COUPLING**

**FIGURE 2.49**



**FULL-COUPLING** Superior to half-coupling. Also requires shaping for connecting to pipe.

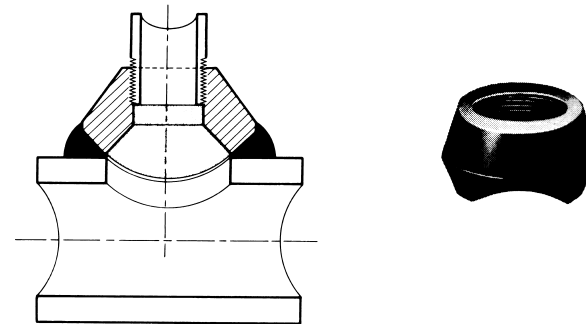
**TANK NIPPLE** See 2.5.1, figure 2.39(d).

The next four fittings for branching are made by Bonny Forge. These fittings offer a means of joining **screwed** piping to a welded run, and for making instrument connections. The advantages are that the welding end does not require reinforcement and that the ends are shaped to the curvature of the run pipe.

**THREDOLET** makes a 90-degree branch, full or reducing, on straight pipe. Flat-based thredolets are available for branch connections on pipe caps and vessel heads.

**THREDOLET**

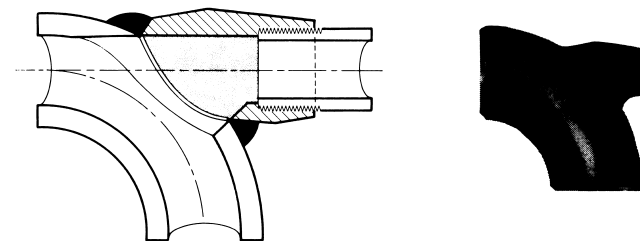
**FIGURE 2.50**



**THREADED ELBOLET** makes reducing tangent branch on long-radius and short radius elbows.

**THREADED ELBOLET**

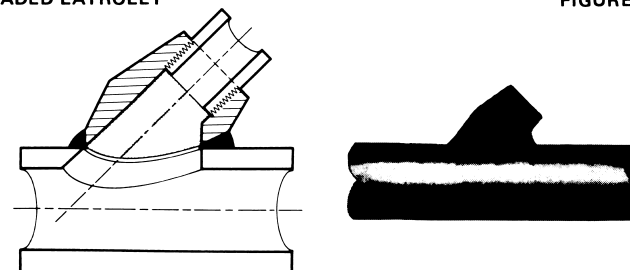
**FIGURE 2.51**



**THREADED LATROLET** makes a 45-degree reducing branch on a straight pipe.

**THREADED LATROLET**

**FIGURE 2.52**



**THREADED NIPOLET** A variant of the thredolet with integral threaded nipple. Primarily developed for small valved connections—see figure 6.47.

#### THREADED NIPOLET

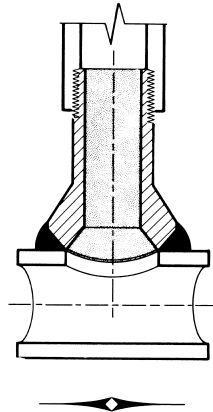


FIGURE 2.53

**STUB-IN** See comments in 2.3.2. Not preferred for branching from pipe smaller than NPS 2 as weld metal may restrict flow.

#### CLOSURES

2.5.4

**CAP** seals the threaded end of pipe.

#### THREADED CAP

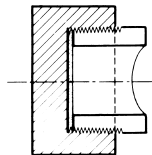


FIGURE 2.54

**BARSTOCK PLUG** seals the threaded end of a fitting. Also termed 'round-head plug'.

#### BARSTOCK PLUG (IN TEE)

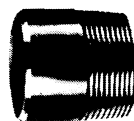
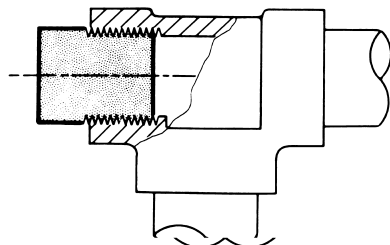


FIGURE 2.55

#### PIPE THREADS

2.5.5

Standard ANSI/ASME B1.20.1 defines general purpose pipe threads: tapered and straight threads for pipe (and fittings, etc.). For the same nominal pipe size, the number of threads per inch is the same for straight and tapered threads. Most pipe joints are made using the tapered thread form.

Tapered and straight threads will mate. Taper/taper and taper/straight (both types) joints are self sealing with the use of pipe dope (a compound spread on the threads which lubricates and seals the joint on assembly), or plastic tape (Teflon). Tape is wrapped around the external thread before the joint is assembled. A straight/straight screwed joint requires locknuts and gaskets to ensure sealing - see fig. 2.39 (d).

Standard ANSI B1.20.3 defines 'dryseal' threads. Dryseal threads seal against line pressure without the use of pipe dope or tape. The seal is obtained by using a modified thread form of sharp crest and flat root. This causes interference (metal-to-metal contact) between the engaged threads, and prevents leakage through the spiral cavity of mating threads.

Symbols used for specifying threads:

N = American National Standard Thread Form, P = Pipe, T = Taper,  
C = Coupling, F = Fuel & Oil, H = Hose coupling, I = Intermediate,  
L = Locknut, M = Mechanical, R = Railing fittings, S = Straight

#### ANSI B1.20.1: PIPE THREADS, GENERAL PURPOSE

|   |      |
|---|------|
| Taper Pipe Thread                                     | NPT  |
| - Rigid mechanical joint for Railings                 | NPTF |
| Straight Pipe Thread:                                 |      |
| - Internal, in Pipe Couplings                         | NPSC |
| - Free-fitting, Mechanical Joints for Fixtures        | NPSM |
| - Loose-fitting, Mechanical Joints with Locknuts      | NPSL |
| - Loose-fitting, Mechanical Joints for Hose Couplings | NPSH |

#### ANSI B1.20.3: DRYSEAL PIPE THREADS

|  |      |
|--|------|
| Taper Pipe Thread:   |      |
| - Dryseal Standard   | NPTF |
| - Dryseal SAE Short (NPTF type, shortened by one thread) PTF-SAE SHORT |      |
| Straight Pipe Thread (internal only):                                  |      |
| - Dryseal, Fuel (for use in soft/ductile materials)                    | NPSF |
| - Dryseal, Intermediate (for use in hard/brittle materials)            | NPSI |

(NPTF is the only type that ensures sealing against line pressure. If there is no objection to its use, pipe dope may be used with all threads to improve sealing, and lessen galling of the threads.)

Specify pipe threads by : NPS - Threads per inch - Thread type

Example: 3 - 8 NPT

## FLANGE FACINGS, BOLTS & GASKETS

2.6

### FLANGE FACINGS & FINISHES

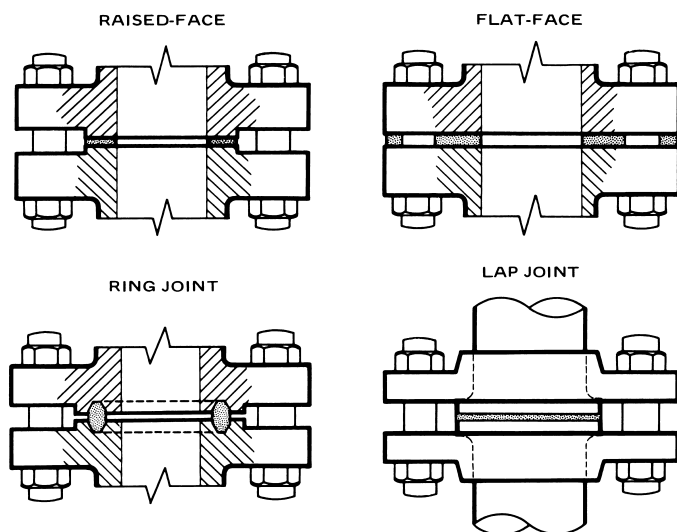
2.6.1

Many facings for flanges are offered by flange manufacturers, including various 'tongue and groove' types which must be used in pairs. However, only four types of facing are widely used, and these are shown in figure 2.56.

The raised face is used for about 80% of all flanges. The ring-joint facing, employed with either an oval-section or octagon-section gasket, is used mainly in the petrochemical industry.

#### THE MOST-USED FLANGE FACINGS

FIGURE 2.56



The **RAISED FACE** is 1/16-inch high for Classes 150 and 300 flanges, and 1/4-inch high for all other classes. Class 250 cast-iron flanges and flanged fittings also have the 1/16-inch raised face.

*Suppliers' catalogs give 'length thru hub' dimensions which include the 0.06-inch raised face on flanges in Classes 150 and 300, but exclude the 0.25-inch raised face on flanges in Classes 400 thru 2500. Tables F include the raised face for all flange Classes.*

**FLAT FACE** Most common uses are for mating with non-steel flanges on bodies of pumps, etc. and for mating with Class 125 cast-iron valves and fittings. Flat-faced flanges are used with a gasket whose outer diameter equals that of the flange — this reduces the danger of cracking a cast-iron, bronze or plastic flange when the assembly is tightened.

**RING-JOINT FACING** is a more expensive facing, and considered the most efficient for high-temperature and high-pressure service. Both flanges of a pair are alike. The ring-joint facing is not prone to damage in handling as the surfaces in contact with the gasket are recessed. Use of facings of this type may increase as hollow metal O-rings gain acceptance for process chemical seals.

**LAP-JOINT FLANGE** is shaped to accommodate the stub end. The combination of flange and stub end presents similar geometry to the raised-face flange and can be used where severe bending stresses will not occur. Advantages of this flange are stated in 2.3.1.

The term 'finish' refers to the type of surface produced by machining the flange face which contacts the gasket. Two principal types of finish are produced, the 'serrated' and 'smooth'.

Forged-steel flanges with raised-face are usually machined to give a 'serrated-concentric' groove, or a 'serrated-spiral' groove finish to the raised-face of the flange. The serrated-spiral finish is the more common and may be termed the 'stock' or 'standard finish' available from suppliers.

The pitch of the groove and the surface finish vary depending on the size and class of the flange. For raised-face steel flanges, the pitch varies from 24 to 40 per inch. It is made using a cutting tool having a minimum radius at the tip of 0.06-inch. The maximum roughness of surface finish is 125-500 microinches.

'Smooth' finish is usually specially-ordered, and is available in two qualities. (1) A fine machined finish leaving no definite tool marks. (2) A 'mirror-finish', primarily intended for use without gaskets.

#### BOLT HOLES IN FLANGES

2.6.2

Bolt holes in flanges are equally spaced. Specifying the number of holes, diameter of the bolt circle and hole size sets the bolting configuration. Number of bolt holes per flange is given in tables F.

Flanges are positioned so that bolts straddle vertical and horizontal centerlines. This is the normal position of bolt holes on all flanged items.

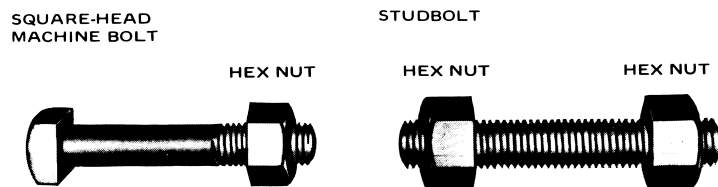
#### BOLTS FOR FLANGES

2.6.3

Two types of bolting are available: the studbolt using two nuts, and the machine bolt using one nut. Both boltings are illustrated in figure 2.57. Studbolt thread lengths and diameters are given in tables F.

Studbolts have largely displaced regular bolts for bolting flanged piping joints. Three advantages of using studbolts are:

- (1) The studbolt is more easily removed if corroded
- (2) Confusion with other bolts at the site is avoided
- (3) Studbolts in the less frequently used sizes and materials can be readily made from round stock



**UNIFIED INCH SCREW THREADS (UN AND UNR THREAD FORM)** UNR indicates rounded root contour, and applies to external threads only. Flat, or rounded root is optional with the UN thread. There are four Unified Screw Threads: Unified Coarse (UNC/ UNCR), Unified Fine (UNF/UNFR), Unified Extra-fine (UNEF/UNEFR) and Unified Selected (UNS/UNSR), with three classes of fit: 1A, 2A and 3A for external threads; 1B, 2B, and 3B for internal threads. (Class 3 has the least clearance.) The standard is ANSI B1.1, which incorporates a metric translation.

UNC (Class 2 medium fit bolt and nut) is used for bolts and studbolts in piping, and specified in the following order:

Diameter - Threads per inch - Thread - Class of fit.

Example: BOLT:  $\frac{1}{2}$  - 13 UNC 2A  
NUT:  $\frac{1}{2}$  - 13 UNC 2B

## GASKETS

### 2.6.4

Gaskets are used to make a fluid-resistant seal between two surfaces. The common gasket patterns for pipe flanges are the full-face and ring types, for use with flat-faced and raised-face flanges respectively. Refer to figure 2.56. Widely-used materials for gaskets are compressed asbestos (1/16-inch thick) and asbestos-filled metal ('spiral-wound', 0.175-inch thick). The filled-metal gasket is especially useful if maintenance requires repeated uncoupling of flanges, as the gasket separates cleanly and is often reusable.

Choice of gasket is decided by:

- (1) Temperature, pressure and corrosive nature of the conveyed fluid
- (2) Whether maintenance or operation requires repeated uncoupling
- (3) Code/environmental requirements that may apply
- (4) Cost

Garlock Incorporated's publication 'Engineered gasketing products' provides information on the suitability of gasket materials for different applications. Table 2.5 gives some characteristics of gaskets, to aid selection.

It may be required that adjacent parts of a line are electrically insulated from one another, and this may be effected by inserting a flanged joint fitted with an insulating gasket set between the parts. A gasket electrically insulates the flange faces, and sleeves and washers insulate the bolts from one or both flanges, as illustrated in figure 2.58.

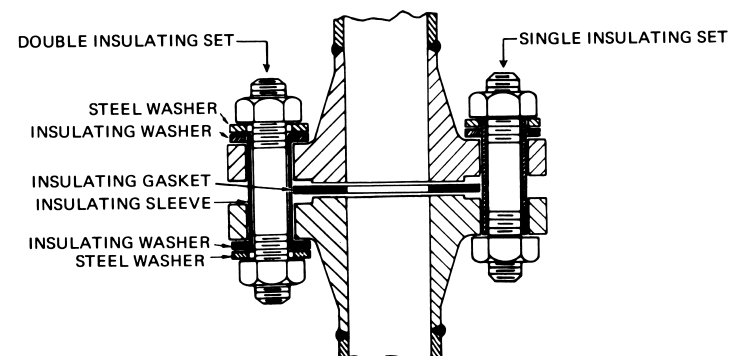
## GASKET CHARACTERISTICS

TABLE 2.5

| GASKET MATERIAL  | EXAMPLE USE                              | MAXIMUM TEMPERATURE (Deg F) | MAXIMUM 'TP' FACTOR Temperature x Pressure (Deg F x PSI) | AVAILABLE THICKNESS (INCHES)  |
|--|--|-----------------------------|--|---|
| Synthetic rubbers  | Water, Air                               | 250                         | 15,000   | 1/32, 1/16, 3/32, 1/8, 1/4  |
| Vegetable fiber  | Oil                                      | 250                         | 40,000   | 1/64, 1/32, 1/16, 3/32, 1/8   |
| Synthetic rubbers with cloth insert ('CI')                             | Water, Air                               | 250                         | 125,000  | 1/32, 1/16, 3/32, 1/8, 1/4  |
| Solid Teflon   | Chemicals                                | 500                         | 150,000  | 1/32, 1/16, 3/32, 1/8   |
| Compressed asbestos  | Most                                     | 750                         | 250,000  | 1/64, 1/32, 1/16, 1/8   |
| Carbon steel   | High-pressure fluids                     | 750                         | 1,600,000  | For ring-joint gaskets, refer to part II  |
| Stainless steel  | High-pressure &/or corrosive fluids      | 1200                        | 3,000,000  |   |
| Spiral-wound:<br>SS/Teflon<br>CS/Asbestos<br>SS/Asbestos<br>SS/Ceramic | Chemicals<br>Most Corrosive<br>Hot gases | 500<br>750<br>1200<br>1900  | } 250,000+   | Most-used thickness for spiral-wound gaskets is 0.175. Alternative gasket thickness: 0.125. |
|  |  |                             |  |   |

## INSULATING GASKET SET

FIGURE 2.58



## TEMPORARY CLOSURES FOR LINES

### 2.7

### IN-LINE CLOSURES

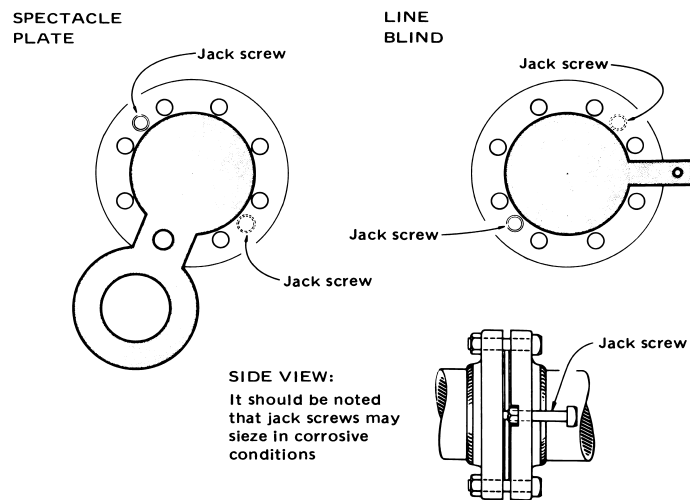
#### 2.7.1

A completely leak-proof means of stopping flow in lines is necessary in piping systems when: (1) A change in process material to flow in the line is to be made and cross-contamination is to be avoided. (2) Periodic maintenance is to be carried out, and a hazard would be presented by flammable and/or toxic material passing a valve.

The valves described in 3.1 may not offer complete security against leakage, and one of the following methods of temporary closure can be used: Line-blind valve, line blind (including special types-for use with ring-joint flanges), spectacle plate (so-called from its shape), 'double block and bleed', and blind flanges replacing a removable spool. The last three closures are illustrated in figures 2.59 thru 2.61.

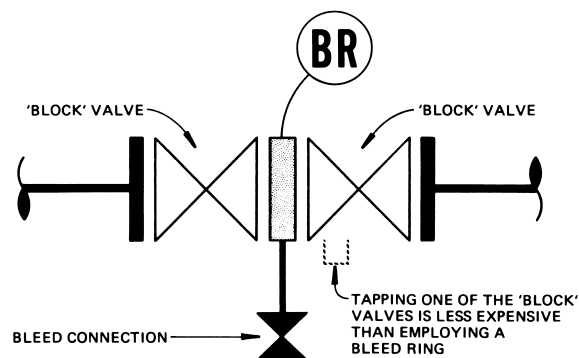
## SPECTACLE PLATE & LINE BLIND

FIGURE 2.59



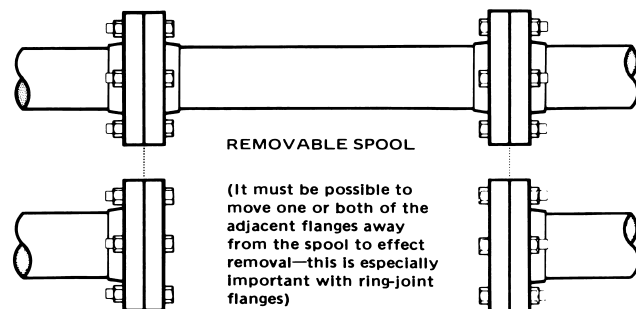
## DOUBLE-BLOCK-AND-BLEED

FIGURE 2.60



## REMOVABLE SPOOL

FIGURE 2.61



If a line is to be temporarily closed down with double-block-and-bleed, both valves are closed, and the fluid between drawn off with the bleed valve. The bleed valve is then left open to show whether the other valves are tightly shut.

Figure 2.60 shows the bleed ring connected to a bleed valve—see 3.1.11. The use of a tapped valve rather than a bleed ring should be considered, as it is a more economic arrangement, and usually can be specified merely by adding a suffix to the valve ordering number.

A line-blind valve is not illustrated as construction varies. This type of valve incorporates a spectacle plate sandwiched between two flanges which may be expanded or tightened (by some easy means), allowing the spectacle plate to be reversed. Constant-length line-blind valves are also available, made to ANSI dimensions for run length.

Table 2.6 compares the advantages of the four in-line temporary closures:

IN-LINE CLOSURES

TABLE 2.6

| CLOSURE<br>CRITERION                 | LINE BLIND<br>VALVE | SPECTACLE<br>PLATE, or<br>LINE BLIND                       | DOUBLE<br>BLOCK, &<br>BLEED | REMOVABLE<br>SPOOL |
|--------------------------------------|---------------------|--|-----------------------------|--------------------|
| RELATIVE<br>OVERALL<br>COST          | LEAST<br>EXPENSIVE  | MEDIUM EXPENSE,<br>DEPENDENT ON FREQUENCY<br>OF CHANGEOVER |                             | MOST<br>EXPENSIVE  |
| MANHOURS<br>FOR DOUBLE<br>CHANGEOVER | NEGLIGIBLE          | 1 to 3   | NEGLIGIBLE                  | 2 to 6             |
| INITIAL<br>COST                      | FAIRLY<br>HIGH      | LOW  | VERY<br>HIGH                | HIGH               |
| CERTAINTY<br>OF SHUT-OFF             | COMPLETE            | COMPLETE   | DOUBTFUL                    | COMPLETE           |
| VISUAL<br>INDICATION?                | YES                 | YES  | YES, BUT<br>SUSPECT         | YES                |
| WHO<br>OPERATES?                     | PLANT<br>OPERATOR   | PIPEFITTER   | PLANT<br>OPERATOR           | PIPEFITTER         |

## CLOSURES FOR PIPE ENDS & VESSEL OPENINGS

### 2.7.2

Temporary bolted closures include blind flanges using flat gaskets or ring joints, T-bolt closures, welded-on closures with hinged doors – including the boltless manhole cover (Robert Jenkins, England) and closures primarily intended for vessels, such as the Lanape range (Bonney Forge) which may also be used with pipe of large diameter. The blind flange is mostly used with a view to future expansion of the piping system, or for cleaning, inspection, etc. Hinged closures are often installed on vessels; infrequently on pipe.

## QUICK CONNECTORS & COUPLINGS

### 2.8

### QUICK CONNECTORS

#### 2.8.1

Two forms of connector specifically designed for temporary use are:

(1) Lever type with double lever clamping, such as Evertite 'Standard' and Victaulic 'Snap Joint'. (2) Screw type with captive nut – 'hose connector'.

Typical use is for connecting temporarily to tank cars, trucks or process vessels. Inter-trades agreements permit plant operators to attach and uncouple these boltless connectors. Certain temporary connectors have built-in valves. Evertite manufactures a double shut-off connector for liquids, and Schrader a valved connector for air lines.

## BOLTED QUICK-COUPPLINGS

2.8.2

Connections of this type may be suitable for either permanent or temporary use, depending on the joint and gasket, and service conditions. Piping can be built rapidly with them, and they are especially useful for making repairs to lines, for constructing short-run process installations such as pilot plants, and for process modification.

### COUPLINGS FOR GROOVED COMPONENTS & PIPE

Couplings of this type are manufactured by the Victaulic Company of America for use with steel, cast-iron, FRP or plastic pipe, either having grooved ends, or with Victaulic collars welded or cemented to the pipe ends.

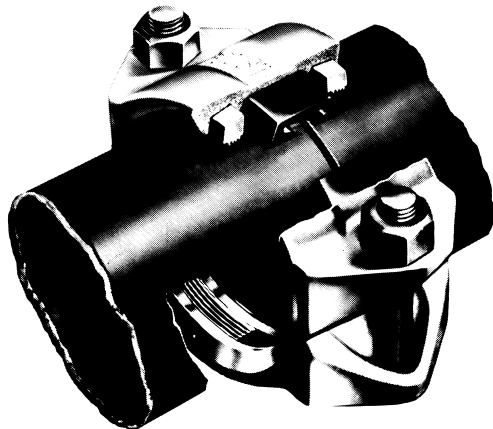
The following special fittings with grooved ends are available: elbow, tee (all types), lateral, cross, reducer, nipple, and cap. Groove-ended valves and valve adaptors are also available. Advantages: (1) Quick fitting and removal. (2) Joint can take up some deflection and expansion. (3) Suitable for many uses, with correct gaskets.

The manufacturer states that the biggest uses are for permanent plant air, water (drinking, service, process, waste) and lubricant lines.

**COMPRESSION SLEEVE COUPLINGS** are extensively used for air, water, oil and gas. Well-known manufacturers include Victaulic, Dresser and Smith-Blair. Advantages: (1) Quick fitting and removal. (2) Joint may take up some deflection and expansion. (3) End preparation of pipe is not needed.

### VICTAULIC COMPRESSION SLEEVE COUPLING

FIGURE 2.62



## EXPANSION JOINTS & FLEXIBLE PIPING

2.9

### EXPANSION JOINTS

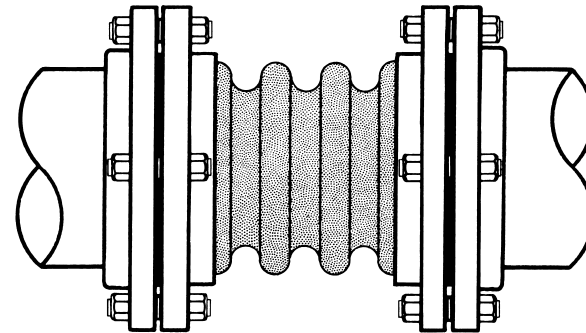
2.9.1

Figures 2.63 thru 2.66 show methods of accommodating movement in piping due to temperature changes, if such movement cannot be taken up by:

(1) Re-routing or re-spacing the line. (2) Expansion loops—see figure 6.1. (3) Calculated placement of anchors. (4) Cold springing—see 6.1. Bellows-type expansion joints of the type shown in figure 2.63 are also used to absorb vibration.

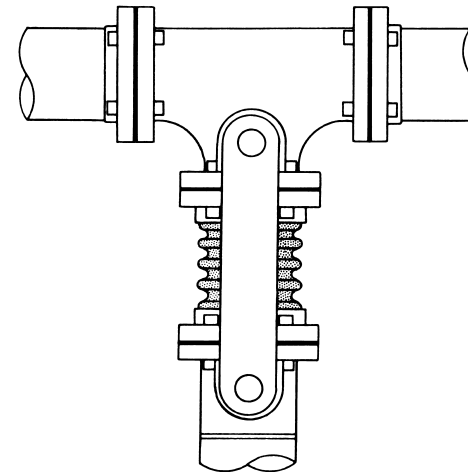
### SIMPLE BELLOWS

FIGURE 2.63



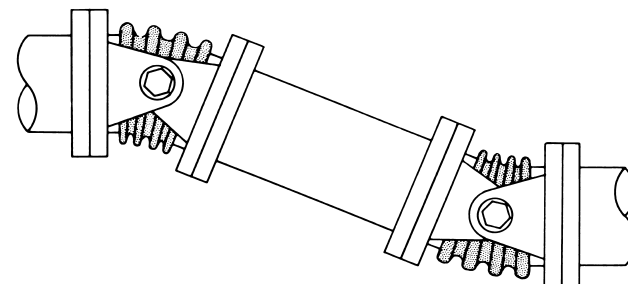
### ARTICULATED BELLOWS

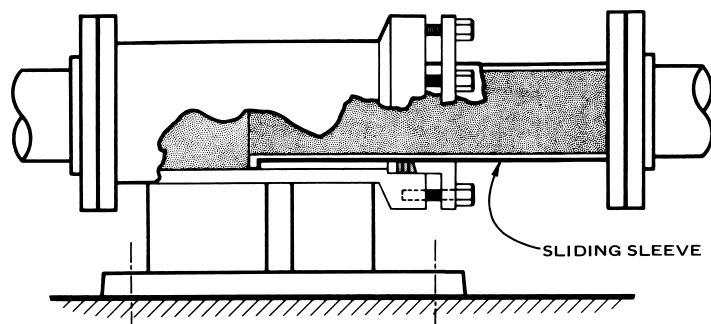
FIGURE 2.64



### ARTICULATED TWIN-BELLOWS ASSEMBLY

FIGURE 2.65



**FLEXIBLE PIPING****2.9.2**

For filling and emptying railcars, tankers, etc., thru rigid pipe, it is necessary to design articulated piping, using 'swiveling' joints, or 'ball' joints (the latter is a 'universal' joint). Flexible hose has many uses especially where there is a need for temporary connections, or where vibration or movement occurs. Chemical-resistant and/or armored hoses are available in regular or jacketed forms (see figure 6.39).

**SEPARATORS, STRAINERS, SCREENS & DRIPLEGS****2.10****COLLECTING UNWANTED MATERIAL FROM THE FLOW****2.10.1**

Devices are included in process and service lines to separate and collect undesirable solid or liquid material. Pipe scale, loose weld metal, unreacted or decomposed process material, precipitates, lubricants, oils, or water may harm either equipment or the process.

Common forms of line-installed separator are illustrated in figures 2.67 and 2.68. Other more elaborate separators mentioned in 3.3.3 are available, but these fall more into the category of process equipment, normally selected by the process engineer.

Air and some other gases in liquid-bearing lines are normally self-collecting at piping high points and at the remote ends of headers, and are vented by discharge valves — see 3.1.9.

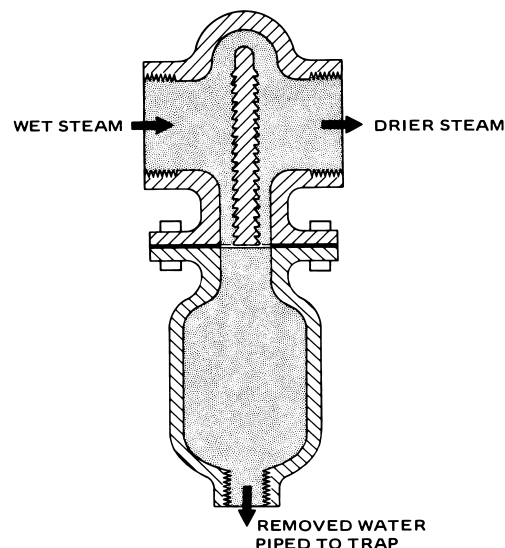
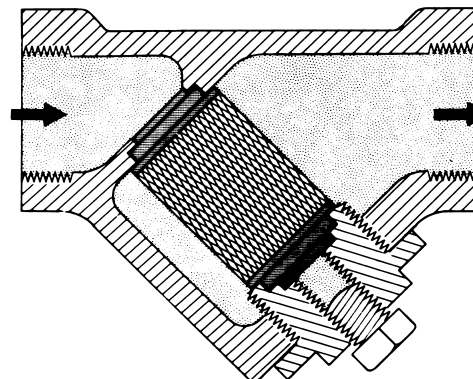
**SEPARATORS****2.10.2**

These permanent devices are used to collect droplets from a gaseous stream, for example, to collect oil droplets from compressed air, or condensate droplets from wet steam. Figure 2.67 shows a separator in which droplets in the stream collect in chevroned grooves in the barrier and drain to the small well. Collected liquid is discharged via a trap—see 3.1.9 and 6.10.7.

**STRAINERS****2.10.3**

Inserted in lines immediately upstream of sensitive equipment, strainers collect solid particles in the approximate size range 0.02–0.5 inch, which can be separated by passing the fluid bearing them thru the strainer's screen. Typical locations for strainers are before a control valve, pump, turbine, or traps on steam systems. 20-mesh strainers are used for steam, water, and heavy or medium oils. 40-mesh is suitable for steam, air, other gases, and light oils.

The commonest strainer is the illustrated wye type where the screen is cylindric and retains the particles within. This type of strainer is easily dismantled. Some strainers can be fitted with a valve to facilitate blowing out collected material without shutting the line down—see figure 6.9, for example. Jacketed strainers are available.

**SEPARATOR****FIGURE 2.67****STRAINER****FIGURE 2.68**

## SCREENS

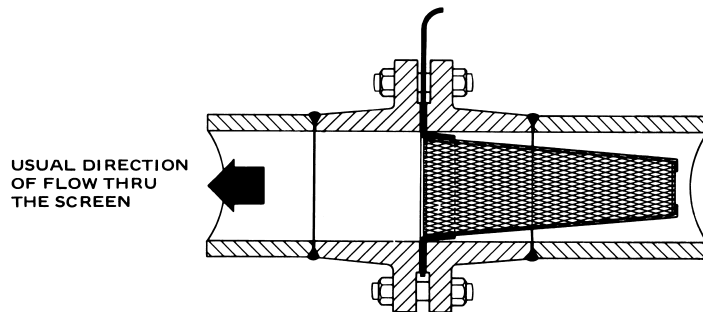
2.10.4

Simple temporary strainers made from perforated sheet metal and/or wire mesh are used for startup operations on the suction side of pumps and compressors, especially where there is a long run of piping before the unit that may contain weld spatter or material inadvertently left in the pipe. After startup, the screen usually is removed.

It may be necessary to arrange for a small removable spool to accommodate the screen. It is important that the flow in suction lines should not be restricted. Cone-shaped screens are therefor preferred, with cylindric types as second choice. Flat screens are better reserved for low-suction heads.

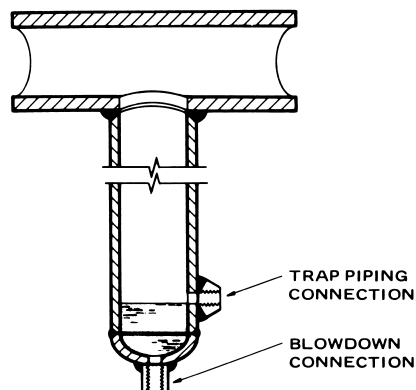
### SCREEN BETWEEN FLANGES

FIGURE 2.69



### DRIPLEG CONSTRUCTION

FIGURE 2.70



## DRIPLEGS

2.10.5

Often made from pipe and fittings, the drip leg is an inexpensive means of collecting condensate. Figure 2.70 shows a drip leg fitted to a horizontal pipe. Removal of condensate from steam lines is discussed in 6.10. Recommended sizes for driplegs are given in table 6.10.

## REINFORCEMENTS

2.11

### BRANCH CONNECTIONS

'Reinforcement' is the addition of extra metal at a branch connection made from a pipe or vessel wall. The added metal compensates for the structural weakening due to the hole.

Stub-ins may be reinforced with regular or wraparound saddles, as shown in figure 2.71. Rings made from platestock are used to reinforce branches made with welded laterals and butt-welded connections to vessels. Small welded connections may be reinforced by adding extra weld metal to the joint.

Reinforcing pieces are usually provided with a small hole to vent gases produced by welding; these gases would otherwise be trapped. A vent hole also serves to indicate any leakage from the joint.

### STRAIGHT PIPE

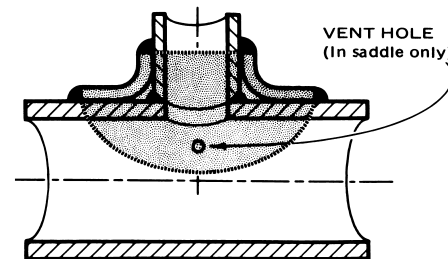
If a butt weld joining two sections of straight pipe is subject to unusual external stress, it may be reinforced by the addition of a 'sleeve' (formed from two units, each resembling the lower member in figure 2.71 (b)).

The code applicable to the piping should be consulted for reinforcement requirements. Backing rings are not considered to be reinforcements—see the footnote to chart 2.1.

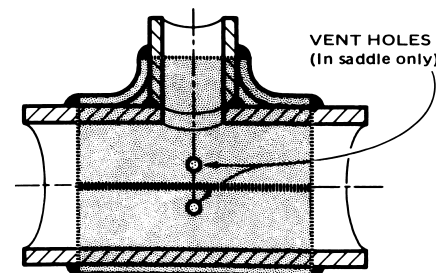
### REINFORCING SADDLES

FIGURE 2.71

#### (a) REGULAR SADDLE

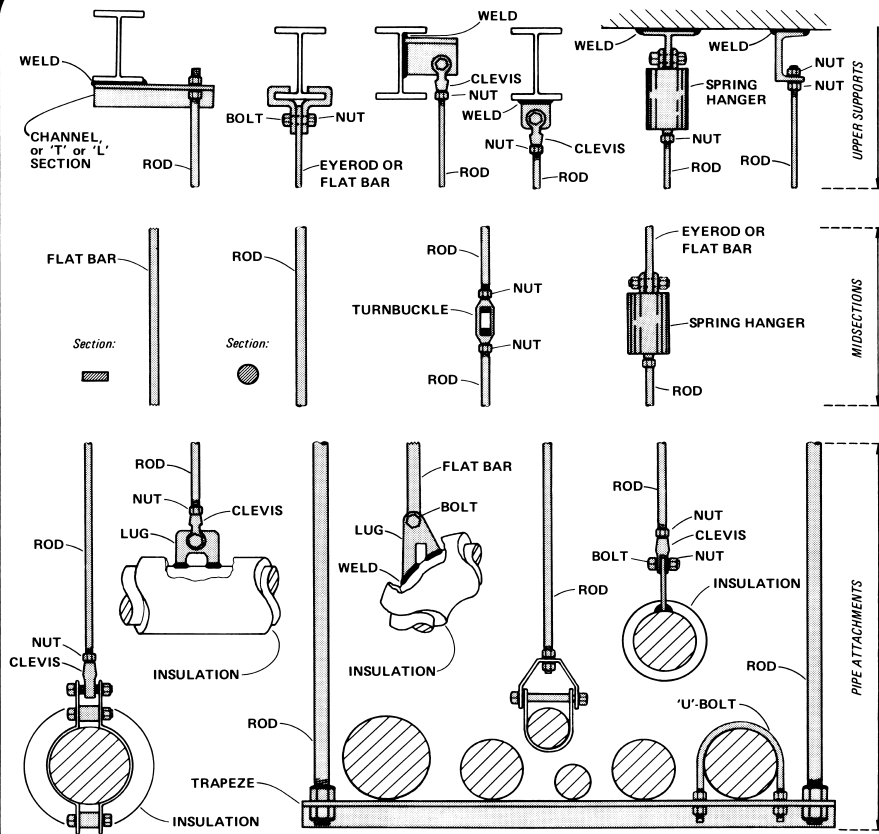


#### (b) WRAPAROUND SADDLE



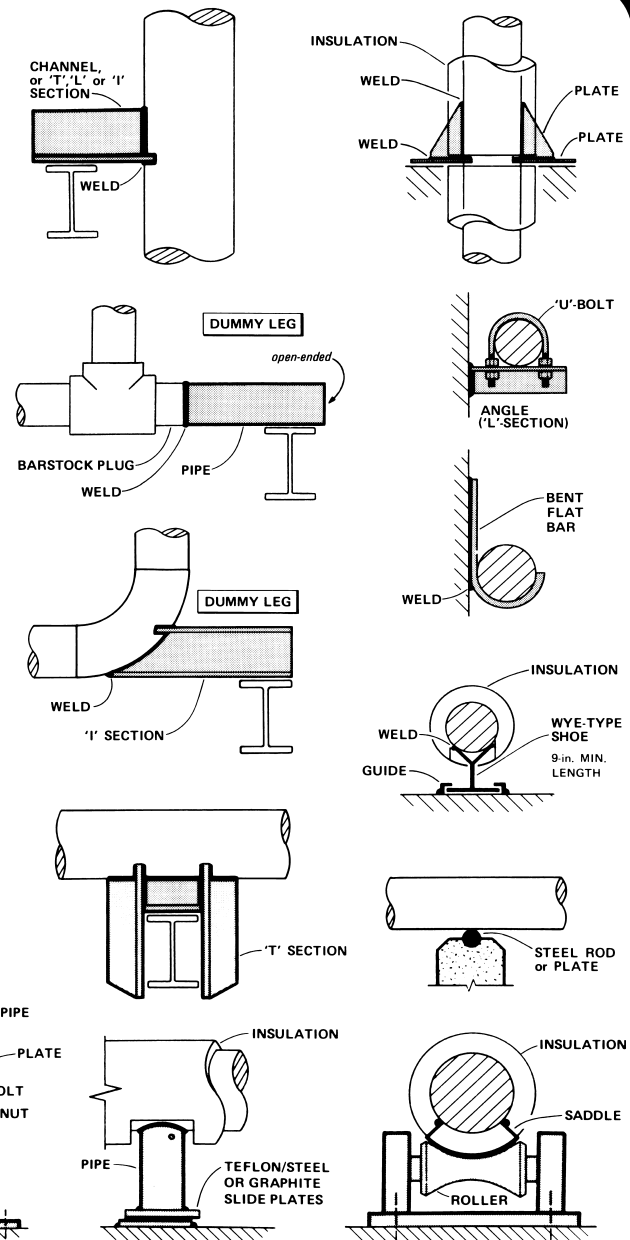
# PIPE SUPPORTS

## HANGERS



# FIGURE 2.72A

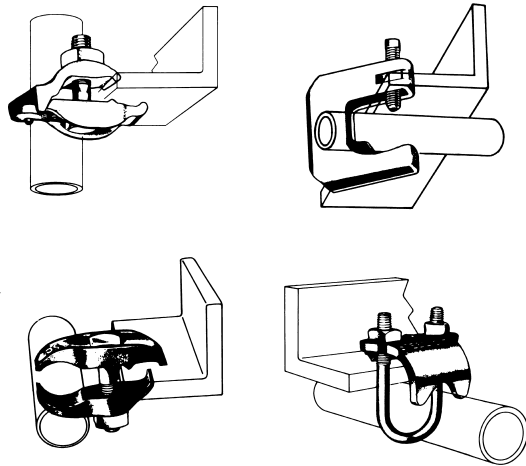
## SUPPORTS



# PIPE SUPPORTS

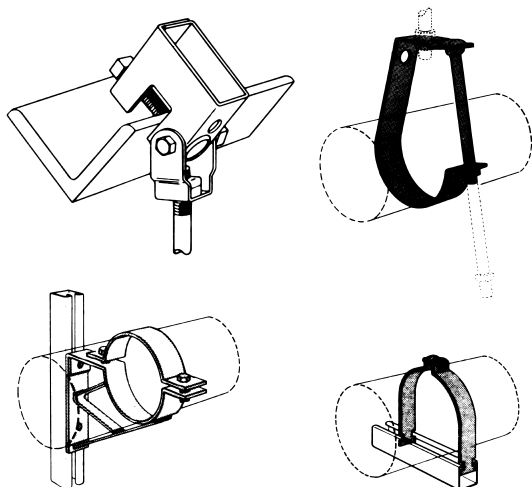
## SUPPORTING PIPE CLOSE TO STRUCTURAL STEEL

(COURTESY STEEL CITY DIVISION, MIDLAND-ROSS CORP)



'KINDORF SYSTEM'

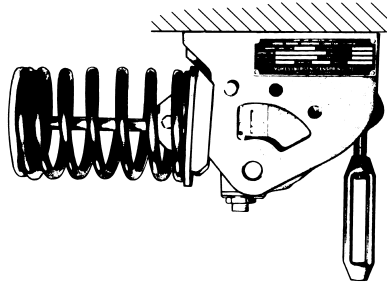
(COURTESY UNISTRUT CORPORATION)



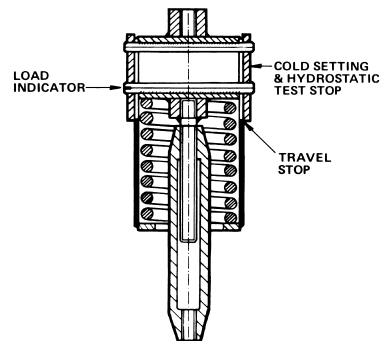
## SPRING HANGERS

(COURTESY VOKES-BERGEN-GENSPRING LTD)

### 1. CONSTANT LOAD TYPE

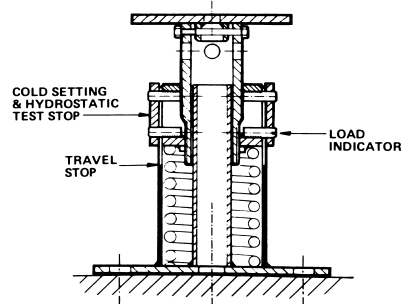


### 2. VARIABLE LOAD TYPE



## SPRING SUPPORT

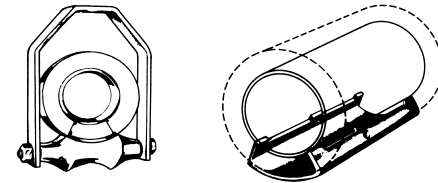
(COURTESY VOKES-BERGEN-GENSPRING LTD)



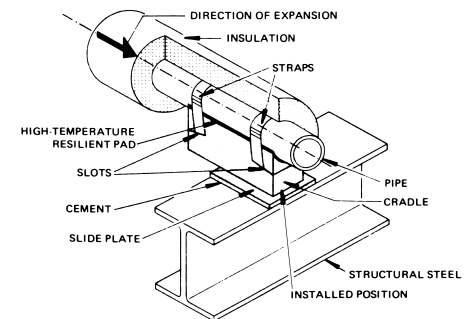
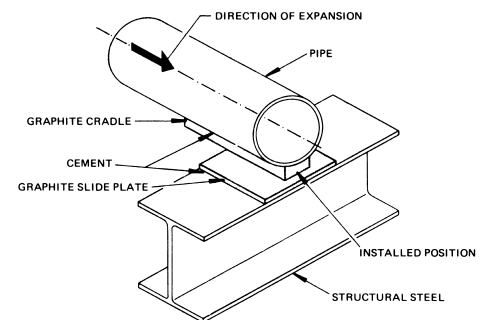
# FIGURE 2.72B

## SUPPORTS ALLOWING FREE MOVEMENT OF PIPE

(COURTESY STEEL CITY DIVISION, MIDLAND-ROSS CORP)



(COURTESY UNION CARBIDE)



## HARDWARE FOR SUPPORTING PIPING

2.12

Symbols for drafting various types of support are shown in chart 5.7. For designing support systems, see 6.2.

### PIPE SUPPORTS

2.12.1

Pipe supports should be as simple as conditions allow. Stock items are used where practicable, especially for piping held from above. To support piping from below, supports are usually made to suit from platestock, pipe, and pieces of structural steel.

A selection of available hardware for supporting is illustrated in figures 2.72A and B.

### TERMS FOR SUPPORTS

2.12.2

**SUPPORT** The weight of piping is usually carried on supports made from structural steel, or steel and concrete. (The term 'support' is also used in reference to hangers.)

**HANGER** Device which suspends piping (usually a single line) from structural steel, concrete or wood. Hangers are usually adjustable for height.

**ANCHOR** A rigid support which prevents transmission of movement (thermal, vibratory, etc.) along piping. Construction may be from steel plate, brackets, flanges, rods, etc. Attachment of an anchor to pipe should preferably encircle the pipe and be welded all around as this gives a better distribution of stress in the pipe wall.

**TIE** An arrangement of one or more rods, bars, etc., to restrain movement of piping.

**DUMMY LEG** An extension piece (of pipe or rolled steel section) welded to an elbow in order to support the line—see figure 2.72A and table 6.3.

The following hardware is used where mechanical and/or thermal movement is a problem:

**GUIDE** A means of allowing a pipe to move along its length, but not sideways.

**SHOE** A metal piece attached to the underside of a pipe which rests on supporting steel. Primarily used to reduce wear from sliding for lines subject to movement. Permits insulation to be applied to pipe.

**SADDLE** A welded attachment for pipe requiring insulation, and subject to longitudinal or rolling movement (resulting from temperature changes other than climatic). Saddles may be used with guides as shown in 6.2.8.

**SLIDE PLATE** A slide plate support is illustrated in figure 2.72A. Figure 2.72B shows applications of 'Ucar' graphite slide plates which are offered by Union Carbide Inc. The two plates used in a support are made from or faced with a material of low friction able to withstand mechanical stress and temperature changes. Plates are often made from graphite blocks. Steel plates with a teflon facing are available and may be welded to steel.

Spring hangers or supports allow variations in the length of pipe due to changes in temperature, and are often used for vertical lines. Refer to 6.2.5 figure 6.16. There are two types of spring hanger or support:

**'CONSTANT LOAD' HANGER** This device consists of a coil spring and lever mechanism in a housing. Movement of the piping, within limits, will not change the spring force holding up the piping; thus, no additional forces will be introduced to the piping system.

**'VARIABLE SPRING' HANGER, and SUPPORT** These devices consist of a coil spring in a housing. The weight of the piping rests on the spring in compression. The spring permits a limited amount of thermal movement. A variable spring hanger holding up a vertical line will reduce its lifting force as the line expands toward it. A variable spring support would increase its lifting force as the line expands toward it. Both place a load on the piping system. Where this is undesirable, a constant-load hanger can be used instead.



### HYDRAULIC DAMPENER, SHOCK, SNUBBER, or SWAY SUPPRESSOR

One end of the unit is attached to piping and the other to structural steel or concrete. The unit expands or contracts to absorb slow movement of piping, but is rigid to rapid movement.

**SWAY BRACE, or SWAY ARRESTOR**, is essentially a helical spring in a housing which is fitted between piping and a rigid structure. Its function is to buffer vibration and sway.

### WELDING TO PIPE

2.12.3

If the applicable code permits, lugs may be welded to pipe. Figure 2.72A illustrates some common arrangements using welded lugs, rolled steel sections and pipe, for:—

- (1) Fixing hangers to structural steel, etc.
- (2) Attaching to pipe
- (3) Supporting pipe

Welding supports to prelined pipe will usually spoil the lining, and therefore lugs, etc., must be welded to pipe and fittings before the lining is applied. Welding of supports and lugs to pipes and vessels to be stress-relieved should be done before heat treatment.

# VALVES, PUMPS, COMPRESSORS, and Types of Process Equipment

## VALVES

3.1

### FUNCTIONS OF VALVES

3.1.1

Table 3.1 gives a basis for classifying valves according to function:

### USES OF VALVES

TABLE 3.1

| VALVE ACTION | EXPLANATION                           | SEE SECTION:            |
|--------------|---------------------------------------|-------------------------|
| ON/OFF       | STOPPING OR STARTING FLOW             | 3.1.4 and 3.1.6         |
| REGULATING   | VARYING THE RATE OF FLOW              | 3.1.5, 3.1.6 and 3.1.10 |
| CHECKING     | PERMITTING FLOW IN ONE DIRECTION ONLY | 3.1.7                   |
| SWITCHING    | SWITCHING FLOW ALONG DIFFERENT ROUTES | 3.1.8                   |
| DISCHARGING  | DISCHARGING FLUID FROM A SYSTEM       | 3.1.9                   |

Types of valve suitable for on/off and regulating functions are listed in chart 3.2. The suitability of a valve for a required purpose depends on its construction, discussed in 3.1.3.

### PARTS OF VALVES

3.1.2

Valve manufacturers' catalogs offer a seemingly endless variety of constructions. Classification is possible, however, by considering the basic parts that make up a valve:

- (1) The 'disc' and 'seat' that directly affect the flow
- (2) The 'stem' that moves the disc — in some valves, fluid under pressure does the work of a stem
- (3) The 'body' and 'bonnet' that house the stem
- (4) The 'operator' that moves the stem (or pressurizes fluid for squeeze valves, etc.)

Figures 3.1 thru 3.3 show three common types of valve with their parts labeled.

### DISC, SEAT, & PORT

Chart 3.1 illustrates various types of disc and port arrangements, and mechanisms used for stopping or regulating flow. The moving part directly affecting the flow is termed the 'disc' regardless of its shape, and the non-moving part it bears on is termed the 'seat'. The 'port' is the maximum internal opening for flow (that is, when the valve is fully open). Discs may be actuated by the conveyed fluid or be moved by a stem having a linear, rotary or helical movement. The stem can be moved manually or be driven hydraulically, pneumatically or electrically, under remote or automatic control, or mechanically by weighted lever, spring, etc.

The size of a valve is determined by the size of its ends which connect to the pipe, etc. The port size may be smaller.

### STEM

There are two categories of screwed stem: The rising stem shown in figures 3.1 and 3.2, and the non-rising stem shown in figure 3.3.

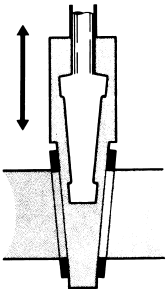
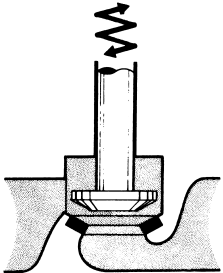
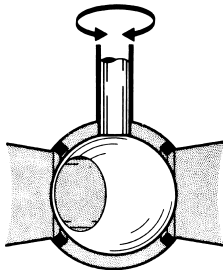
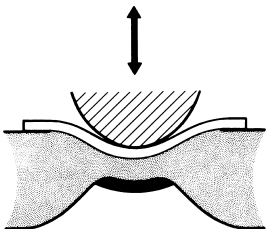
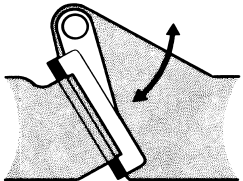
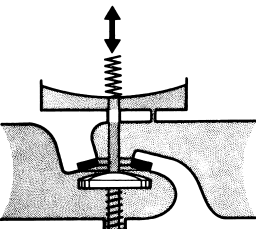
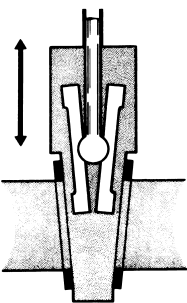
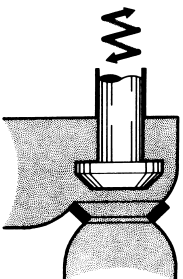
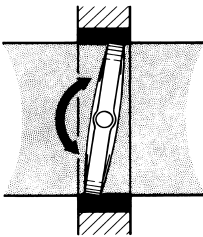
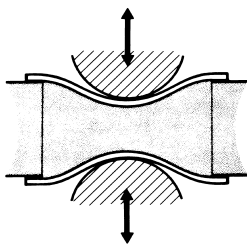
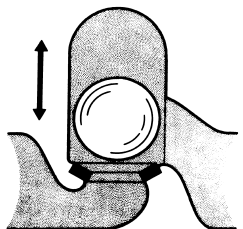
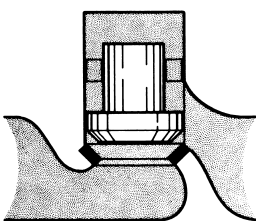
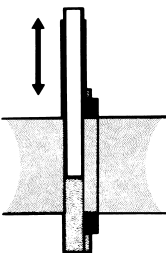
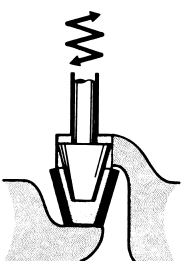
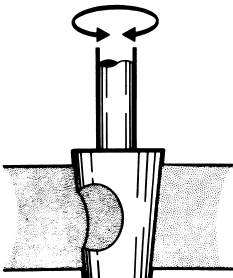
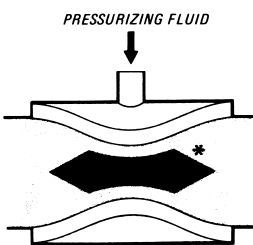
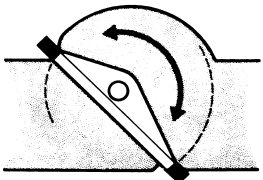
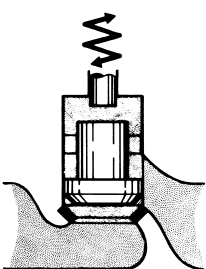
Rising stem (gate and globe) valves are made either with 'inside screw' (IS) or 'outside screw' (OS). The OS type has a yoke on the bonnet and the assembly is referred to as 'outside screw and yoke', abbreviated to 'OS&Y'. The handwheel can either rise with the stem, or the stem can rise thru the handwheel.

# BASIC VALVE MECHANISMS

## FLUID CONTROL ELEMENTS (DISCS)

CHART 3.1

IN THESE SCHEMATIC DIAGRAMS, THE DISC IS SHOWN WHITE, THE SEAT IN SOLID COLOR, & THE CONVEYED FLUID SHADED.

| OPERATED VALVES   |   |   |  | SELF-OPERATED VALVES  |   |
|---|---|---|--|---|---|
| GATE  | GLOBE   | ROTARY  | DIAPHRAGM  | CHECK   | REGULATING  |
|  <p>SOLID-WEDGE GATE</p>                   |  <p>GLOBE</p>        |  <p>ROTARY-BALL</p>    |  <p>DIAPHRAGM<br/>(SAUNDERS TYPE)</p>                                  |  <p>SWING CHECK</p>          |  <p>PRESSURE REGULATOR</p> |
|  <p>SPLIT-WEDGE GATE</p>                  |  <p>ANGLE GLOBE</p> |  <p>BUTTERFLY</p>     |  <p>PINCH</p>   |  <p>BALL CHECK</p>          |  <p>PISTON CHECK</p>      |
|  <p>SINGLE-DISC<br/>SINGLE-SEAT GATE</p> |  <p>NEEDLE</p>     |  <p>PLUG or COCK</p> |  <p>PRESSURIZING FLUID<br/>*Central seat is optional<br/>SQUEEZE</p> |  <p>TILTING DISC CHECK</p> |  <p>STOP CHECK</p>       |

Non-rising stem valves are of the gate type. The handwheel and stem are in the same position whether the valve is open or closed. The screw is inside the bonnet and in contact with the conveyed fluid.

A 'floor stand' is a stem extension for use with both types of stem, where it is necessary to operate a valve thru a floor or platform. Alternately, rods fitted with universal joints may be used to bring a valve handwheel within an operator's reach.

Depending on the size of the required valve and availabilities, selection of stem type can be based on:

- (1) Whether it is undesirable for the conveyed fluid to be in contact with the threaded bearing surfaces
- (2) Whether an exposed screw is liable to be damaged by abrasive atmospheric dust
- (3) Whether it is necessary to see if the valve is open or closed

In addition to the preceding types of stem used with gate and globe valves, most other valves have a simple rotary stem. Rotary-ball, plug and butterfly valves have a rotary stem which is moved by a permanent lever, or tool applied to a square boss at the end of the stem.

## BONNET

There are three basic types of attachment for valve bonnets: screwed (including union), bolted, and breechlock.

A screwed bonnet may occasionally stick and turn when a valve is opened. Although sticking is less of a problem with the union type bonnet, valves with screwed bonnets are best reserved for services presenting no hazard to personnel. Union bonnets are more suitable for small valves requiring frequent dismantling than the simple screwed type.

The bolted bonnet has largely displaced screwed and union bonnet valves in hydrocarbon applications. A U-bolt or clamp-type bonnet is offered on some small gate valves for moderate pressures, to facilitate frequent cleaning and inspection.

The 'pressure seal' is a variation of the bolted bonnet used for high-pressure valves, usually combined with OS&Y construction. It makes use of line pressure to tighten and seal an internal metal ring or gasket against the body.

The breechlock is a heavier infrequently-used and more expensive construction, also for high-pressure use, and involves seal-welding of the bonnet with the body.

FIGURE 3.1

GATE VALVE (OS&Y, bolted bonnet, rising stem)

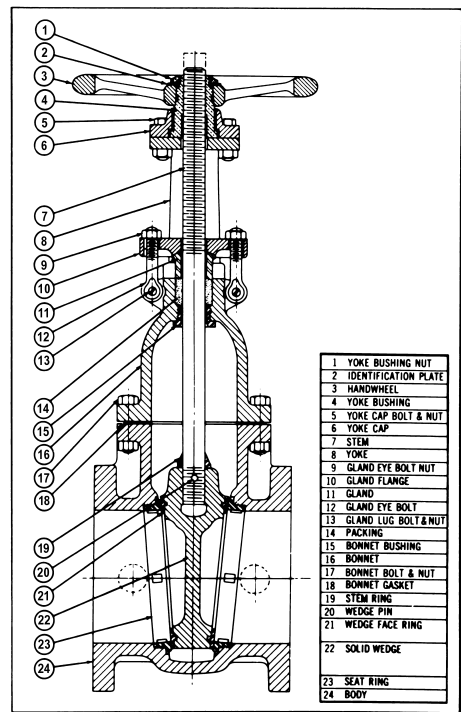


FIGURE 3.2

GLOBE VALVE (OS&Y, bolted bonnet, rising stem)

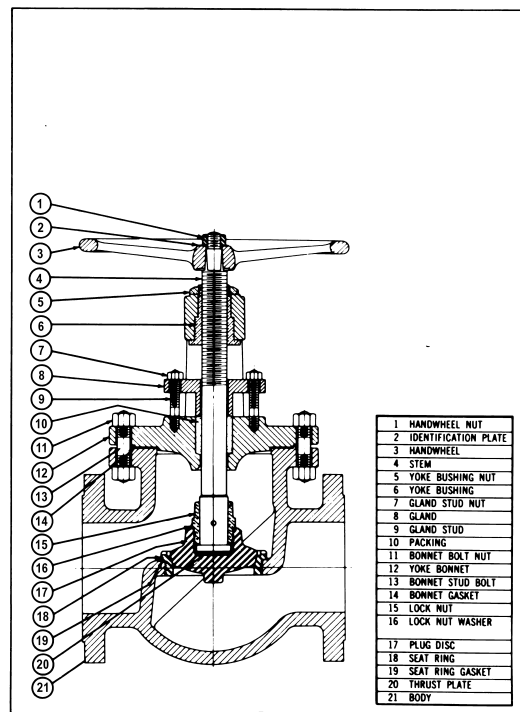
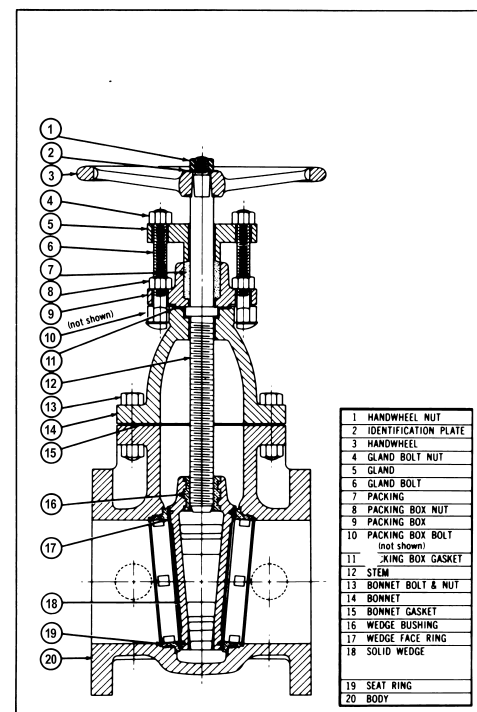


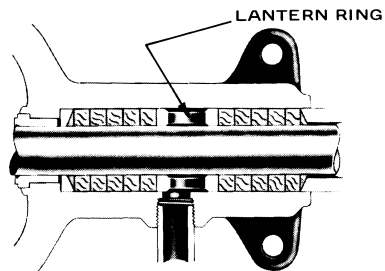
FIGURE 3.3

GATE VALVE (IS, bolted bonnet, non-rising stem)



A critical factor for valves used for process chemicals is the lubrication of the stem. Care has to be taken in the selection of packing, gland design, and choice and application of lubricant. As an option the bonnet may include a 'lantern ring' which serves two purposes — either to act as a collection point to drain off any hazardous seepages, or as a point where lubricant can be injected.

#### LANTERN RING



#### BODY

Selection of material to fabricate the interior of the valve body is important with a valve used for process chemicals. There is often a choice with regard to the body and trim, and some valves may be obtained with the entire interior of the body lined with corrosion-resistant material.

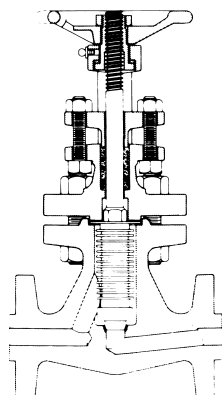
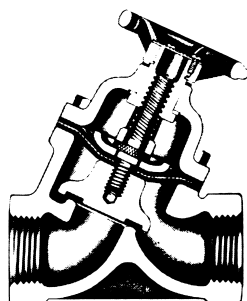
Valves are connected to pipe, fittings or vessels by their body ends, which may be flanged, screwed, butt- or socket-welding, or finished for hose, Victaulic coupling, etc. Jacketed valves are also available—see 6.8.2.

#### SEAL

In most stem-operated valves, whether the stem has rotary or lineal movement, packing or seals are used between stem and bonnet (or body). If high vacuum or corrosive, flammable or toxic fluid is to be handled, the disc or stem may be sealed by a metal bellows, or by a flexible diaphragm (the latter is termed 'packless' construction). A gasket is used as a seal between a bolted bonnet and valve body.

#### BELLOWS-SEAL VALVE

#### 'PACKLESS' VALVE

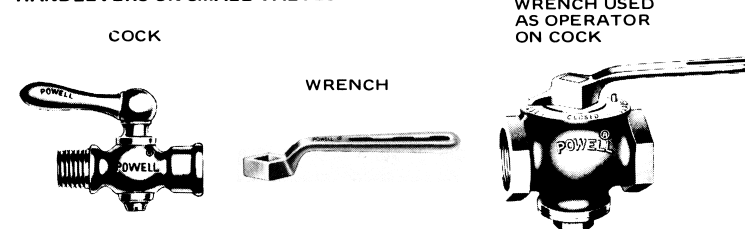


Flanged valves use gaskets to seal against the line flanges. Butterfly valves may extend the resilient seat to also serve as line gaskets. The pressure-seal bonnet joint utilizes the pressure of the conveyed fluids to tighten the seal — see 'Pressure seal' under 'Bonnet', this section.

#### MANUAL OPERATORS

**HANDLEVER** is used to actuate the stems of small butterfly and rotary-ball valves, and small cocks. Wrench operation is used for cocks and small plug valves.

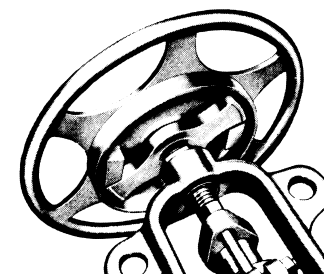
#### HANDLEVERS ON SMALL VALVES



**HANDWHEEL** is the most common means for rotating the stem on the majority of popular smaller valves such as the gate, globe and diaphragm types. Additional operating torque for gate and globe valves is offered by 'hammerblow' or 'impact' handwheels which may be substituted for normal handwheels if easier operation is needed but where gearing is unnecessary.

#### HAMMER-BLOW HANDWHEEL

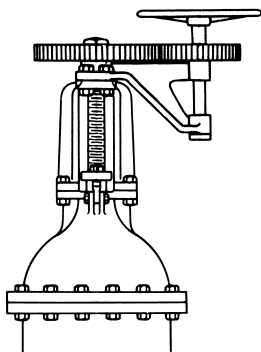
HAMMER ACTION IS PROVIDED BY TWO LUGS CAST ON UNDER-SIDE OF HANDWHEEL, WHICH HIT ANVIL PROJECTING BETWEEN



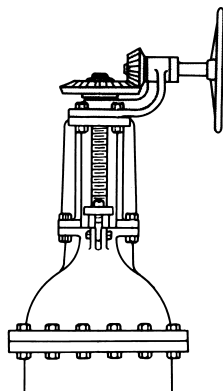
**CHAIN** operator is used where a handwheel would be out of reach. The stem is fitted with a chainwheel or wrench (for lever-operated valves) and the loop of the chain is brought within 3 ft of working floor level. Universal-type chainwheels which attach to the regular handwheel have been blamed for accidents: in corrosive atmospheres where an infrequently-operated valve has stuck, the attaching bolts have been known to fail. This problem does not arise with the chainwheel that replaces the regular valve handwheel.

**GEAR** operator is used to reduce the operating torque. For manual operation, consists of a handwheel-operated gear train actuating the valve stem. As a guide, gear operators should be considered for valves of the following sizes and classes: 125, 150, and 300, 14-inch and larger; 400 and 600, 8-inch and larger; 900 and 1500, 6-inch and larger; 2500, 4-inch and larger.

#### SPUR-GEAR OPERATOR



#### BEVEL-GEAR OPERATOR



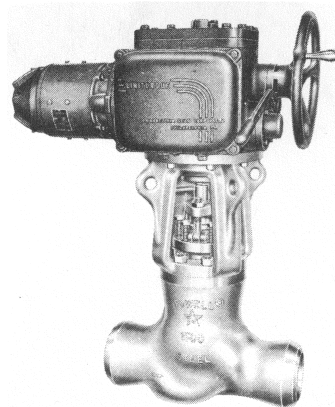
#### POWERED OPERATORS

Electric, pneumatic or hydraulic operation is used: (1) Where a valve is remote from the main working area. (2) If the required frequency of operation would need unreasonable human effort. (3) If rapid opening and/or closing of a valve is required.

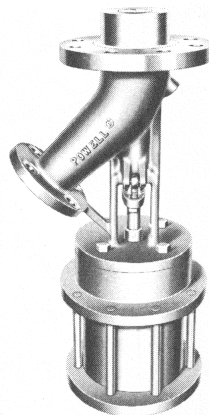
**ELECTRIC MOTOR** The valve stem is moved by the electric motor, thru reducing gears.

**SOLENOID** may be used with fast-acting check valves, and with on/off valves in light-duty instrumentation applications.

#### ELECTRIC MOTOR OPERATOR



#### PNEUMATIC OPERATOR



**PNEUMATIC & HYDRAULIC OPERATORS** may be used where flammable vapor is likely to be present. They take the following forms: (1) Cylinder with double-acting piston driven by air, water, oil, or other liquid which usually actuates the stem directly. (2) Air motor which actuates the stem thru

gearing—these motors are commonly piston-and-cylinder radial types. (3) A double-acting vane with limited rotary movement in a sector casing, actuating the stem directly. (4) Squeeze type (refer to 'Squeeze valve').

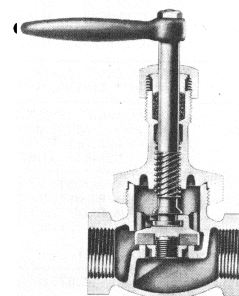
#### QUICK-ACTING OPERATORS FOR NON-ROTARY VALVES (Manually-operated valves)

Quick-acting operators are used with gate and globe valves. Two stem movements are employed:—

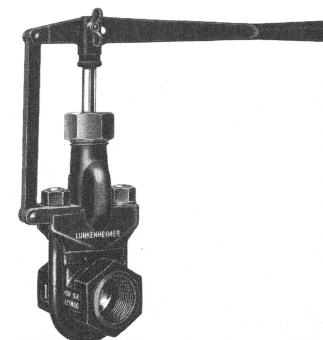
- (1) Rotating stem, rotated by a lever
- (2) Sliding stem, in which the stem is raised and lowered by lever

#### QUICK-ACTING LEVERS ON VALVES

(1) Rotating stem on globe valve



(2) Sliding stem on gate valve



Steam and air whistles are examples of the use of sliding-stem quick-acting operators with globe valves.

#### SELECTING ON/OFF & REGULATING VALVES

#### 3.1.3

The suitability of a valve for a particular service is decided by its materials of construction in relation to the conveyed fluid as well as its mechanical design. Referring to the descriptions in 3.1.2, the steps in selection are to choose:

(1) Material(s) of construction. (2) The disc type. (3) Stem type. (4) Means of operating the stem — the 'operator'. (5) Bonnet type. (6) Body ends — welding, flanged, etc. (7) Delivery time. (8) Price. (9) Warranty of performance for severe conditions.

Chart 3.2 is a guide to valve selection, and indicates valves which may be chosen for a given service. The chart should be read from left to right. First, ascertain whether a liquid, gas or powder is to be handled by the valve. Next, consider the nature of the fluid—whether it is foodstuffs or drugs to be handled hygienically, chemicals that are corrosive, or whether the fluid is substantially neutral or non-corrosive.

Next consider the function of the valve — simple open-or-closed operation ('on/off'), or regulating for control or for dosing. These factors decided, the chart will then indicate types of valves which should perform satisfactorily in the required service.

If the publication is available, reference should also be made to the Crane Company's 'Choosing the right valve'.

# VALVE SELECTION GUIDE

## CHART 3.2

| CONVEYED FLUID | NATURE OF FLUID<br>See Note (2) in Key          | VALVE FUNCTION         | TYPE OF DISC   | SPECIAL FEATURES<br>(.....) denotes Limitation. (.....) denotes Option.  |
|----------------|---|------------------------|--|--|
| LIQUID         | NEUTRAL<br>(WATER, OIL, Etc.)                   | ON/OFF                 | GATE<br>ROTARY BALL<br>PLUG<br>DIAPHRAGM<br>BUTTERFLY<br>PLUG GATE | NONE<br>NONE<br>NONE<br>[For oil: No natural rubber]<br>NONE<br>NONE   |
|                |   | REGULATING             | GLOBE<br>BUTTERFLY<br>PLUG GATE<br>DIAPHRAGM<br>NEEDLE             | NONE<br>NONE<br>NONE<br>[For oil: No natural rubber]<br>NONE, [Small flows only]   |
|                | CORROSIVE<br>(ALKALINE, ACID, Etc.)             | ON/OFF                 | GATE<br>PLUG GATE<br>ROTARY BALL<br>PLUG<br>DIAPHRAGM<br>BUTTERFLY | ANTI-CORROSIVE*, (OS&Y), (Bellows seal)<br>ANTI-CORROSIVE*, (OS&Y)<br>ANTI-CORROSIVE*, (Lined)<br>ANTI-CORROSIVE*, (Lubricated), (Lined)<br>ANTI-CORROSIVE*, (Lined)<br>ANTI-CORROSIVE*, (Lined) |
|                |   | REGULATING             | GLOBE<br>DIAPHRAGM<br>BUTTERFLY<br>PLUG GATE                       | ANTI-CORR*, (OS&Y), (Diaphragm or Bellows Seal)<br>ANTI-CORROSIVE*, (Lined)<br>ANTI-CORROSIVE*, (Lined)<br>ANTI-CORROSIVE*, (OS&Y)   |
|                | HYGIENIC<br>(BEVERAGES, FOOD and DRUGS)         | ON/OFF                 | BUTTERFLY<br>DIAPHRAGM   | SPECIAL DISC†, WHITE SEAT †<br>SANITARY LINING, WHITE DIAPHRAGM †  |
|                |   | REGULATING             | BUTTERFLY<br>DIAPHRAGM<br>SQUEEZE<br>PINCH                         | SPECIAL DISC†, WHITE SEAT †<br>SANITARY LINING, WHITE DIAPHRAGM †<br>WHITE FLEXIBLE TUBE †<br>WHITE FLEXIBLE TUBE †  |
|                | SLURRY  | ON/OFF                 | ROTARY BALL<br>BUTTERFLY<br>DIAPHRAGM<br>PLUG<br>PINCH<br>SQUEEZE  | ABRASION-RESISTANT LINING<br>ABRASION-RESIST. DISC, RESILIENT SEAT<br>ABRASION-RESISTANT LINING<br>LUBRICATED, (Lined)<br>NONE<br>CENTRAL SEAT   |
|                |   | REGULATING             | BUTTERFLY<br>DIAPHRAGM<br>SQUEEZE<br>PINCH<br>GATE                 | ABRASION-RESIST. DISC, RESILIENT SEAT<br>LINED*<br>NONE<br>NONE<br>SINGLE SEAT, NOTCHED DISC   |
|                | FIBROUS<br>SUSPENSIONS                          | ON/OFF &<br>REGULATING | GATE<br>DIAPHRAGM<br>SQUEEZE<br>PINCH                              | SINGLE SEAT, KNIFE-EDGED DISC, NOTCHED DISC<br>NONE<br>NONE<br>NONE  |
| GAS            | NEUTRAL<br>(AIR, STEAM, Etc.)                   | ON/OFF                 | GATE<br>GLOBE<br>ROTARY BALL<br>PLUG<br>DIAPHRAGM                  | NONE<br>(Composition Disc), (Plug-Type Disc)<br>NONE<br>NONE, [Unsuitable for steam service]<br>NONE, [Unsuitable for steam service]   |
|                |   | REGULATING             | GLOBE<br>NEEDLE<br>BUTTERFLY<br>DIAPHRAGM<br>GATE                  | NONE<br>NONE, [Small flows only]<br>NONE<br>NONE, [Unsuitable for steam service]<br>SINGLE SEAT  |
|                | CORROSIVE<br>(ACID VAPORS, CHLORINE, Etc.)      | ON/OFF                 | BUTTERFLY<br>ROTARY BALL<br>DIAPHRAGM<br>PLUG                      | ANTI-CORROSIVE*<br>ANTI-CORROSIVE*<br>ANTI-CORROSIVE*<br>ANTI-CORROSIVE*   |
|                |   | REGULATING             | BUTTERFLY<br>GLOBE<br>NEEDLE<br>DIAPHRAGM                          | ANTI-CORROSIVE*<br>ANTI-CORROSIVE*, (OS&Y)<br>ANTI-CORROSIVE*, [Small flows only]<br>ANTI-CORROSIVE*   |
|                | VACUUM  | ON/OFF                 | GATE<br>GLOBE<br>ROTARY BALL<br>BUTTERFLY                          | BELLOWS SEAL<br>DIAPHRAGM or BELLOWS SEAL<br>NONE<br>RESILIENT SEAT  |
| SOLID          | ABRASIVE<br>POWDER<br>(SILICA, Etc.)            | ON/OFF &<br>REGULATING | PINCH<br>SQUEEZE<br>SPIRAL SOCK                                    | NONE<br>(CENTRAL SEAT)<br>NONE   |
|                | LUBRICATING<br>POWDER<br>(GRAPHITE, TALC, Etc.) | ON/OFF &<br>REGULATING | PINCH<br>GATE<br>SQUEEZE<br>SPIRAL SOCK                            | NONE<br>SINGLE SEAT<br>(CENTRAL SEAT)<br>NONE  |

\* Suitability of materials of construction with respect to the great variety of fluids encountered is a complex topic. A good general reference is the current edition of the Chemical Engineer's Handbook

† The disc should be smooth, without bolts and recesses, in a sanitary material such as stainless steel, or fully coated with 'white' plastic or rubber material. 'White' means that the material does not contain a filler which is toxic or can discolor the product.

### KEY TO VALVE SELECTION GUIDE

#### CHART 3.2

- Determine type of conveyed fluid—liquid, gas slurry, or powder
- Determine nature of fluid:
  - Substantially neutral—not noticeably acid or alkaline, such as various oils, drinking water, nitrogen, gas, air, etc.
  - Corrosive—markedly acid, alkaline, or otherwise chemically reactive
  - 'Hygienic'—materials for the food, drug, cosmetic or other industries
  - Slurry—suspension of solid particles in a liquid can have an abrasive effect on valves, etc. Non-abrasive slurries such as wood-pulp slurries can choke valve mechanisms
- Determine operation:
  - 'On/off'—fully open or fully closed
  - Regulating—including close regulation (throttling)
- Look into other factors affecting choice:
  - Pressure and temperature of conveyed fluid
  - Method of operating stem—consider closing time
  - Cost
  - Availability
  - Special installation problems—such as welding valves into lines. Welding heat will sometimes distort the body and affect the sealing of small valves.

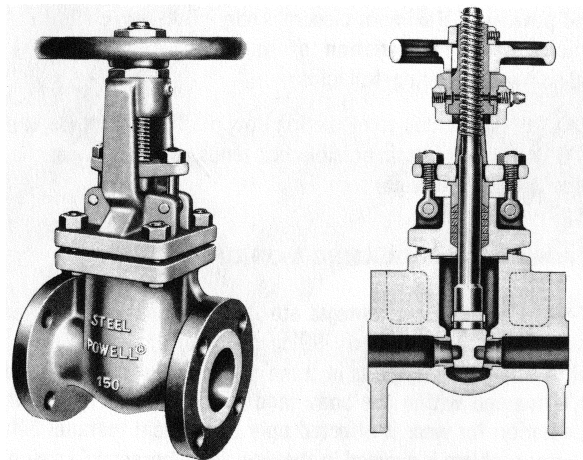
## VALVES MAINLY FOR ON/OFF SERVICE

### 3.1.4

In industrial piping, on/off control of flow is most commonly effected with gate valves. Most types of gate valve are unsuitable for regulating: erosion of the seat and disc occurs in the throttling position due to vibration of the disc ("chattering"). With some fluids, it may be desirable to use globe valves for on/off service, as they offer tighter closure. However, as the principal function of globe valves is regulation, they are described in 3.1.5.

**SOLID WEDGE GATE VALVE** has either a solid or flexible wedge disc. In addition to on/off service, these valves can be used for regulating, usually in sizes 6-inch and larger, but will chatter unless disc is fully guided throughout travel. Suitable for most fluids including steam, water, oil, air and gas. The flexible wedge was developed to overcome sticking on cooling in high-temperature service, and to minimize operating torque. The flexible wedge is not illustrated—it can be likened to two wheels set on a very short axle.

#### SOLID WEDGE GATE VALVE



**DOUBLE-DISC PARALLEL-SEATS GATE VALVE** has two parallel discs which are forced, on closure, against parallel seats by a 'spreader'. Used for liquids and gases at normal temperatures. Unsuitable for regulation. To prevent jamming, installation is usually vertical with handwheel up.

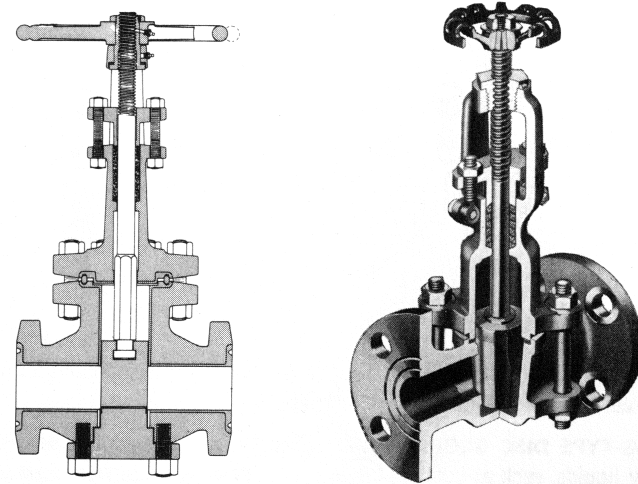
**DOUBLE-DISC (SPLIT-WEDGE) WEDGE GATE VALVE** Discs wedge against inclined seats without use of a spreader. Remarks for double-disc parallel seats gate valve apply, but smaller valves are made for steam service. Often, construction allows the discs to rotate, distributing wear.

**SINGLE-DISC SINGLE-SEAT GATE VALVE, or SLIDE VALVE,** is used for handling paper pulp slurry and other fibrous suspensions, and for low-pressure gases. Will not function properly with inflow on the seat side. Suitable for regulating flow if tight closure is not required.

**SINGLE-DISC PARALLEL-SEATS GATE VALVE** Unlike the single-seat slide valve, this valve affords closure with flow in either direction. Stresses on stem and bonnet are lower than with wedge-gate valves. Primarily used for liquid hydrocarbons and gases.

#### SINGLE-DISC PARALLEL-SEATS GATE VALVE

#### PLUG GATE VALVE



**PLUG GATE VALVE** This valve has a round tapered disc which moves up and down. Suitable for throttling and full-flow use, but only available in the smaller sizes.

**PLUG VALVE** Mechanism is shown in chart 3.1, but the disc may be cylindrical as well as tapered. Advantages are compactness, and rotary 90-degree stem movement. The tapered plug tends to jam and requires a high operating torque: this is overcome to some extent by the use of a low-friction (teflon, etc.) seat, or by lubrication (with the drawback that the conveyed fluid is contaminated). The friction problem is also met by mechanisms raising the disc from the seat before rotating it, or by using the 'eccentric' design (see rotary-ball valve). Principal uses are for water, oils, slurries, and gases.

**LINE-BLIND VALVE** This is a positive shutoff device which basically consists of a flanged assembly sandwiching a spectacle-plate or blind. This valve is described and compared with other closures in 2.7.1.

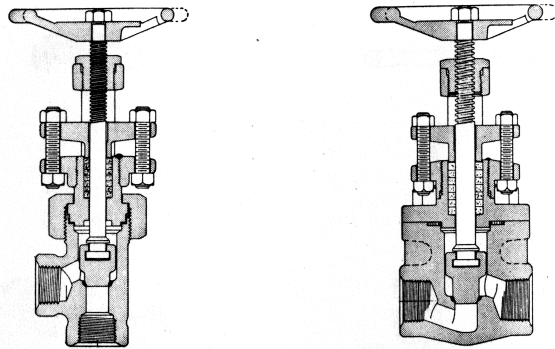
## VALVES MAINLY FOR REGULATING SERVICE

### 3.1.5

**GLOBE VALVE, STRAIGHT & ANGLE TYPE** These are the valves most used for regulating. For line sizes over 6-inch, choice of a valve for flow control tends to go to suitable gate or butterfly valves. For more satisfactory service, the direction of flow thru valve recommended by manufacturers is from stem to seat, to assist closure and to prevent the disc chattering against the seat in the throttling position. Flow should be from seat to stem side (1) if there is a hazard presented by the disc detaching from the stem thus closing the valve, or (2) if a composition disc is used, as this direction of flow then gives less wear.

**ANGLE VALVE** This is a globe valve with body ends at right angles, saving the use of a 90-degree elbow. However, the angles of piping are often subject to higher stresses than straight runs, which must be considered with this type of valve.

#### GLOBE VALVES

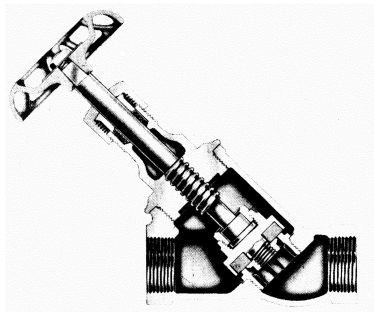


**REGULAR-DISC GLOBE VALVE** Unsuitable for close regulation as disc and seat have narrow (almost line) contact.

**PLUG-TYPE DISC GLOBE VALVE** Used for severe regulating service with gritty liquids, such as boiler feedwater, and for blow-off service. Less subject to wear under close regulation than the regular-seated valve.

**WYE-BODY GLOBE VALVE** has in-line ports and stem emerging at about 45 degrees; hence the 'Y'. Preferred for erosive fluids due to smoother flow pattern.

#### WYE-BODY GLOBE VALVE (Incorporating composition disc)

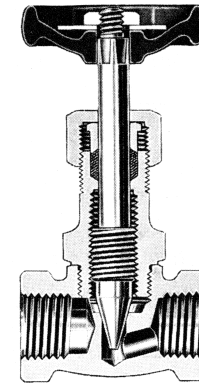


**COMPOSITION-DISC GLOBE VALVE** Suitable for coarse regulation and tight shutoff. Replaceable composition-disc construction is similar to that of a faucet. Grit will imbed in the soft disc preventing seat damage and ensuring good closure. Close regulating will rapidly damage the seat.

**DOUBLE-DISC GLOBE VALVE** features two discs bearing on separate seats spaced apart on a single shaft, which frees the operator from stresses set up by the conveyed fluid pressing into the valve. Principle is used on control valves and pressure regulators for steam and other gases. Tight shutoff is not ensured.

**NEEDLE VALVE** is a small valve used for flow control and for dosing liquids and gases. Resistance to flow is precisely controlled by a relatively large seat area and the adjustment afforded by fine threading of the stem.

#### NEEDLE VALVE



**SQUEEZE VALVE** is well-suited to regulating the flow of difficult liquids, slurries and powders. Maximum closure is about 80%, which limits the range of regulation, unless the variation of this type of valve with a central core (seat) is used, offering full closure.

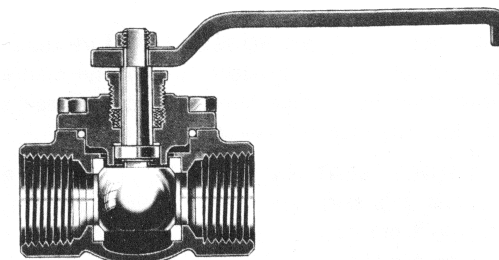
**PINCH VALVE** Also suited to regulating flow of difficult liquids, slurries and powders. Complete closure is possible but tends to rapidly wear the flexible tube, unless of special design.

#### VALVES FOR BOTH REGULATING & ON/OFF SERVICE

3.1.6

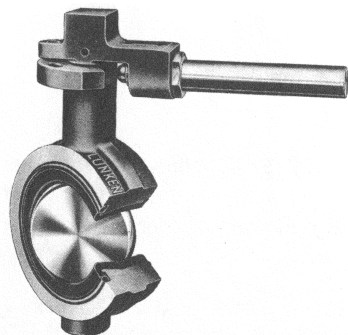
**ROTARY-BALL VALVE** Advantages are low operating torque, availability in large sizes, compactness, rotary 90-degree stem movement, and 'in-line' replaceability of all wearing parts in some designs. Possible disadvantages are that fluid is trapped within the body (and within the disc on closure), and that compensation for wear is effected only by resilient material behind the seats: the latter problem is avoided in the single-seat 'eccentric' version, which has the ball slightly offset so that it presses into the seat, on closure. Principal uses are for water, oils, slurries, gases and vacuum. Valve is available with a ball having a shaped port for regulation.

#### ROTARY-BALL VALVE



**BUTTERFLY VALVE** offers the advantages of rotary stem movement (90 degrees or less), compactness, and absence of pocketing. It is available in all sizes, and can be produced in chemical-resistant and hygienic forms. The valves are used for gases, liquids, slurries, powders and vacuum. The usual resilient plastic seat has a temperature limitation, but tight closure at high temperatures is available with a version having a metal ring seal around the disc. If the valve is flanged, it may be held between flanges of any type. Slip-on and screwed flanges do not form a proper seal with some wafer forms of the valve, in which the resilient seat is extended to serve also as line gaskets.

**BUTTERFLY VALVE**  
(Wafer type)



**VALVES FOR CHECKING BACKFLOW**

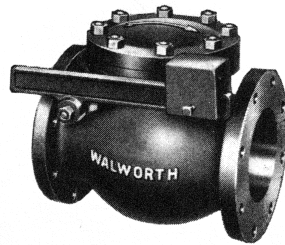
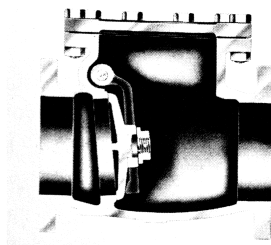
3.1.7

All valves in this category are designed to permit flow of liquid or gas in one direction and close if flow reverses.

**SWING CHECK VALVE** The regular swing check valve is not suitable if there is frequent flow reversal as pounding and wearing of disc occurs. For gritty liquids a composition disc is advisable to reduce damage to the seat. May be mounted vertically with flow upward, or horizontally. Vertically-mounted valve has a tendency to remain open if the stream velocity changes slowly. An optional lever and outside weight may be offered either to assist closing or to counterbalance the disc in part, and allow opening by low-pressure fluid.

**SWING CHECK VALVES**

Outside Lever & Weight  
for swing check valve



**TILTING-DISC VALVE** Suitable where frequent flow reversal occurs. Valve closes rapidly with better closure and less slamming than the swing check valve, which it somewhat resembles. It has higher pressure drop with large

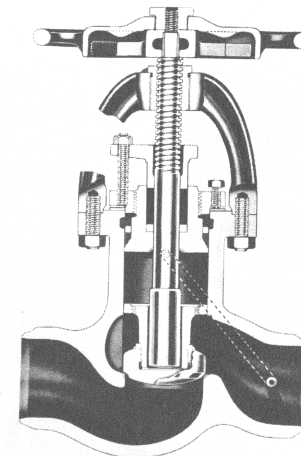
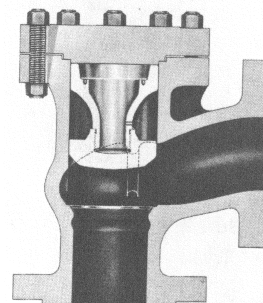
flow velocities and lower-pressure drop with small velocities than a comparable swing-check valve. May be installed vertically with flow upward, or horizontally. Disc movement can be controlled by an integral dashpot or snubber.

**LIFT-CHECK VALVE** resembles the piston-check valve. The disc is guided, but the dashpot feature is absent. Spring-loaded types can operate at any orientation, but unsprung valves have to be arranged so that the disc will close by gravity. Composition-disc valves are available for gritty liquids.

**PISTON-CHECK VALVE** Suitable where frequent change of direction of flow occurs as these valves are much less subject to pounding with pulsating flow due to the integral dash-pot. Spring-loaded types can operate at any orientation. Unsprung valves have to be orientated for gravity closure. Not suitable for gritty liquids.

**STOP CHECK VALVE**

**PISTON-CHECK VALVE**



**STOP-CHECK VALVE** Principal example of use is in steam generation by multiple boilers, where a valve is inserted between each boiler and the main steam header. Basically, a check valve that optionally can be kept closed automatically or manually.

**BALL-CHECK VALVE** is suitable for most services. The valve can handle gases, vapors and liquids, including those forming gummy deposits. The ball seats by gravity and/or back pressure, and is free to rotate, which distributes wear and aids in keeping contacting surfaces clean.

**WAFER CHECK VALVE** effects closure by two semicircular 'doors', both hinged to a central post in a ring-shaped body which is installed between flanges. Frequently used for non-fouling liquids, as it is compact and of relatively low cost. A single disc type is also available.

**FOOT VALVE** Typical use is to maintain a head of water on the suction side of a sump pump. The valve is basically a lift-check valve with a strainer integrated.

## VALVES FOR SWITCHING FLOW

### 3.1.8

**MULTIPOINT VALVE** Used largely on hydraulic and pneumatic control circuits and sometimes used directly in process piping, these valves have rotary-ball or plug-type discs with one or more ports arranged to switch flow.

**DIVERTING VALVE** Two types of 'diverting' valve are made. Both switch flow from a line into one of two outlets. One type is of wye pattern with a hinged disc at the junction which closes one of the two outlets, and is used to handle powders and other solids. The second type handles liquid only, and has no moving parts—flow is switched by two pneumatic control lines. It is available in sizes to 6-inch.

## VALVES FOR DISCHARGING

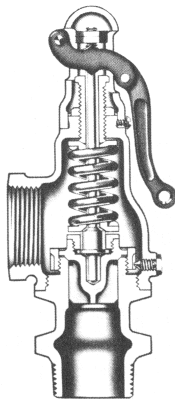
### 3.1.9

These valves allow removal of fluid from within a piping system either to atmosphere, to a drain, or to another piping system or vessel at a lower pressure. Operation is often automatic. Relief and safety valves, steam traps, and rupture discs are included in this section. Pressure-relieving valves are usually spring loaded, as those worked by lever and weight can be easily rendered inoperative by personnel. The first three valves are operated by system pressure, and are usually mounted directly onto the piping or vessel to be protected, in a vertical, upright position. Refer to the governing code for the application of these valves, including the need for an external lifting device (handlever, etc.).

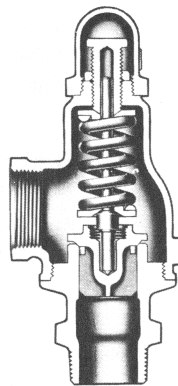
**SAFETY VALVE** A rapid-opening (popping action) full-flow valve for air and other gases.

**RELIEF VALVE** Intended to relieve excess pressure in liquids, in situations where full-flow discharge is not required, when release of a small volume of liquid would rapidly lower pressure. Mounting is shown in figure 6.4.

SAFETY VALVE



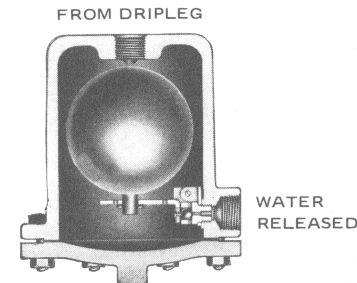
RELIEF VALVE



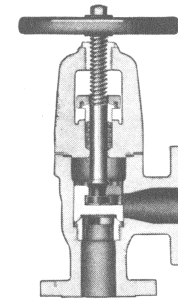
**SAFETY-RELIEF VALVE** Relieves excess pressure of either gas or liquid which may suddenly develop a vapor phase due to rapid and uncontrolled heating from chemical reaction in liquid-laden vessels. Refer to figure 6.4.

**BALL FLOAT VALVE** These automatic valves are used: (1) As air traps to remove water from air systems. (2) To remove air from liquid systems and act as vacuum breakers or breather valves. (3) To control liquid level in tanks. They are not intended to remove condensate.

**BALL FLOAT VALVE**  
(For first use above)



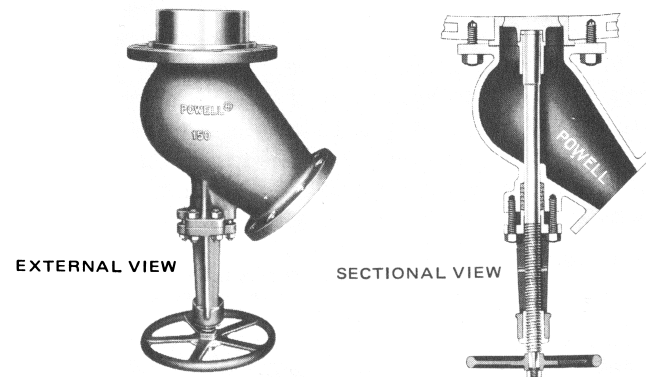
**BLOWOFF VALVE**



**BLOWOFF VALVE** A variety of globe valve conforming with boiler code requirements and especially designed for boiler blowoff service. Sometimes suitable also for blowdown service. Wye-pattern and angle types often used. Used to remove air and other gases from boilers, etc. Manually-operated.

**FLUSH-BOTTOM TANK VALVE** Usually a globe type, designed to minimize pocketing, primarily for conveniently discharging liquid from the low point of a tank.

**FLUSH-BOTTOM TANK VALVE (GLOBE TYPE)**

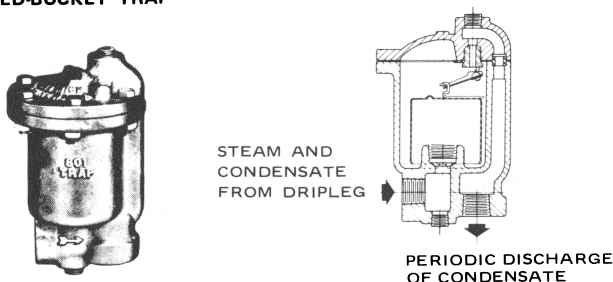


**RUPTURE DISC** A safety device designed to burst at a certain excess pressure and rapidly discharge gas or liquid from a system. Usually made in the form of a replaceable metal disc held between flanges. Disc may also be of graphite or, for lowest bursting pressures, plastic film.

**SAMPLING VALVE** A valve, usually of needle or globe pattern, placed in a branch line for the purpose of drawing off samples of process material thru the branch. Sampling from very high pressure lines is best done thru a double valved collecting vessel. A cooling arrangement may be needed for sampling from high-temperature lines.

**TRAP** An automatic valve for: (1) Discharging condensate, air and gases from steam lines without releasing steam. (2) Discharging water from air lines without releasing air—see 'Ball float valve', this section.

#### INVERTED-BUCKET TRAP



### CONTROL VALVES & PRESSURE REGULATORS

3.1.10

#### CONTROL VALVES

Control valves automatically regulate pressure and/or flow rate, and are available for any pressure. If different plant systems operate up to, and at pressure/temperature combinations that require Class 300 valves, sometimes (where the design permits), all control valves chosen will be Class 300 for interchangeability. However, if none of the systems exceeds the ratings for Class 150 valves, this is not necessary. The control valve is usually chosen to be smaller than line size to avoid throttling and consequent rapid wear of the seat.

Globe-pattern valves are normally used for control, and their ends are usually flanged for ease of maintenance. The disc is moved by a hydraulic, pneumatic, electrical, or mechanical operator.

Figure 3.4 shows schematically how a control valve can be used to control rate of flow in a line. Flow rate is related to the pressure drop across the 'sensing element' (an orifice plate in this instance—see 6.7.5). The 'controller' receives the pressure signals, compares them with the pressure drop for the desired flow and, if the actual flow is different, adjusts the control valve to increase or decrease the flow.

Comparable arrangements to figure 3.4 can be devised to control any of numerous process variables—temperature, pressure, level and flow rate are the most common controlled variables.

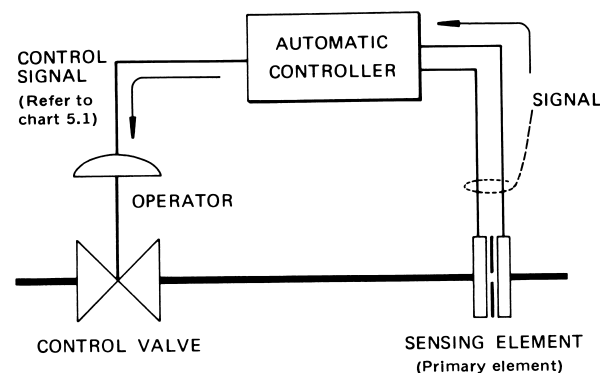
Control valves may be self-operating, and not require the addition of a controller, sensing element, etc. Pressure regulators are a common example of this type of valve, and chart 3.1 shows the principles of operation of a pressure regulator.

**PRESSURE REGULATOR** Control valve of globe type which adjusts downstream pressure of liquid or gas (including steam or vapors) to a lower desired value ('set pressure').

**BACK-PRESSURE REGULATOR** Control valve used to maintain upstream pressure in a system.

#### SCHEMATIC FOR A CONTROL VALVE ARRANGEMENT

FIGURE 3.4



### UNCLASSIFIED VALVES & TERMS

3.1.11

With few exceptions, the following are not special valve types different from those previously discussed, but are terms used to describe valves by service or function.

**BARSTOCK VALVE** Any valve having a body machined from solid metal (barstock). Usually needle or globe type.

**BIBB** A small valve with turned-down end, like a faucet.

**BLEED VALVE** Small valve provided for drawing off fluid.

**BLOCK VALVE** An on/off valve, nearly always a gate valve, placed in lines at battery limits.

**BLOWDOWN VALVE** Usually refers to a plug-type disc globe valve used for removing sludge and sedimentary matter from the bottom of boiler drums, vessels, driplegs, etc.

**BREATHING VALVE** A special self-acting valve installed on storage tanks, etc., to release vapor or gas on slight increase of internal pressure (in the region of ½ to 3 ounces per square inch).

**BYPASS VALVE** Any valve placed in a bypass arranged around another valve or equipment—see 6.1.3 under 'If there is no P&ID....' and figures 6.6 thru 6.11.

**DIAPHRAGM VALVE** Examples of true diaphragm valves, where the diaphragm closes off the flow, are shown in chart 3.1. These forms of diaphragm valve are popular for regulating the flow of slurries and corrosive fluids and for vacuum. The term 'diaphragm valve' is also applied to valves which have a diaphragm seal between stem and body, but these are better referred to as 'diaphragm seal' or 'packless' valves—see 3.1.2, under 'Seal'.

**DRAIN VALVE** A valve used for the purpose of draining liquids from a line or vessel. Selection of a drain valve, and the method of attachment, is influenced by the undesirability of pocketing the material being drained—this is important with slurries and liquids which are subject to: (1) Solidification on cooling or polymerization. (2) Decomposition.

**DRIP VALVE** A drain valve fitted to the bottom of a dripleg to permit blowdown.

**FLAP VALVE** A non-return valve having a hinged disc or rubber or leather flap, used for low-pressure lines.

**HEADER VALVE** An isolating valve installed in a branch where it joins a header.

**HOSE VALVE** A gate or globe valve having one of its ends externally threaded to one of the hose thread standards in use in the USA. These valves are used for vehicular and firewater connections.

**ISOLATING VALVE** An on/off valve isolating a piece of equipment or a process from piping.

**KNIFE-EDGE VALVE** A single-disc single-seat gate valve (slide gate) with a knife-edged disc.

**MIXING VALVE** regulates the proportions of two inflows to produce a controlled outflow.

**NON-RETURN VALVE** Any type of stop-check valve—see 3.1.7.

**PAPER-STOCK VALVE** A single-disc single-seat gate valve (slide gate) with knife-edged or notched disc used to regulate flow of paper slurry or other fibrous slurry.

**PRIMARY VALVE** See 'Root valve', this section.

**REGULATING VALVE** Any valve used to adjust flow.

**ROOT VALVE** (1) A valve used to isolate a pressure element or instrument from a line or vessel. (2) A valve placed at the beginning of a branch from a header.

**SAMPLING VALVE** Small valve provided for drawing off fluid. See 3.1.9.

**SHUTOFF VALVE** An on/off valve placed in lines to or from equipment, for the purpose of stopping and starting flow.

**SLURRY VALVE** A knife-edge valve used to control flow of non-abrasive slurries.

**SPIRAL-SOCK VALVE** A valve used to control flow of powders by means of a twistable fabric tube or sock.

**STOP VALVE** An on/off valve, usually a globe valve.

**THROTTLING VALVE** Any valve used to closely regulate flow in the just-open position.

**VACUUM BREAKER** A special self-acting valve, or any valve suitable for vacuum service, operated manually or automatically, installed to admit gas (usually atmospheric air) into a vacuum or low-pressure space. Such valves are installed on high points of piping or vessels to permit draining, and sometimes to prevent siphoning.

**UNLOADING VALVE** See 3.2.2, under 'Unloading', and figure 6.23.

**QUICK-ACTING VALVE** Any on/off valve rapidly operable, either by manual lever, spring, or by piston, solenoid or lever with heat-fusible link releasing a weight which in falling operates the valve. Quick-acting valves are desirable in lines conveying flammable liquids. Unsuitable for water or for liquid service in general without a cushioning device (hydraulic accumulator, 'pulsation pot' or 'standpipe') to protect piping from shock. See 3.1.2, under 'Quick-acting operators for non-rotary valves'.

## PUMPS & COMPRESSORS

3.2

### PUMPS

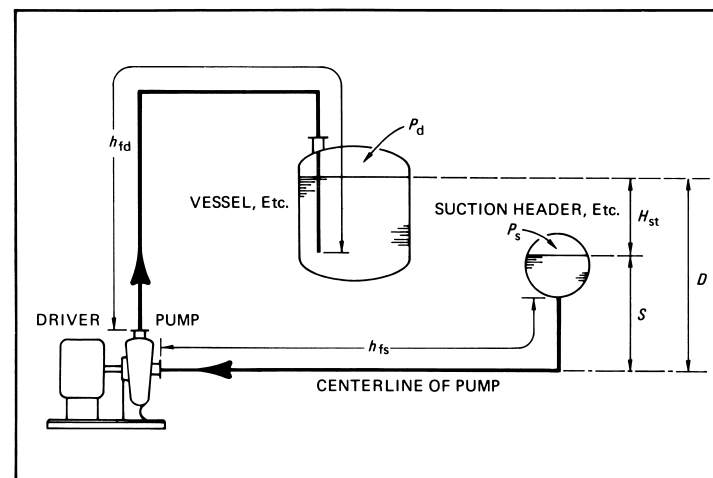
3.2.1

#### DRIVERS

Electric motors are the most frequently used drivers. Larger pumps may be driven by steam-, gas-, or diesel-engines, or by turbines.

'HEADS' (PRESSURES) IN PUMP PIPING

FIGURE 3.5



#### NOTES

The total head,  $H$ , which must be provided by the pump in the arrangement shown, is:—

$$H = h_d - h_s = H_{st} + (h_{fd} + h_{fs}) + (P_d - P_s)$$

Heads may be expressed either all in absolute units or all in gage units, but not in mixed units. The various head terms in this equation are, with reference to the illustration:—

$h_d$  = total discharge head

$h_s$  = total suction head

$H_{st}$  = static head (differential) =  $D - S$

$h_{fd}$  = friction head loss in discharge piping, including exit loss (as liquid discharges into vessel, etc.) and loss at increaser located at pump outlet\*

$h_{fs}$  = friction head loss in suction piping, including entrance loss (as liquid enters line from header, etc.) and loss at reducer located at pump inlet\*

$P_d$  = pressure head above liquid level in discharge vessel or header

$P_s$  = pressure head above liquid level in suction header or vessel

#### NET POSITIVE SUCTION HEAD (NPSH)

'NPSH' is defined by:—  $S - h_{fs} + P_s - P_{vp}$ , where

$P_{vp}$  = vapor pressure of liquid at temperature of liquid at suction header, etc. Vapor pressures are given in absolute units

\*Table F-10 gives entrance loss, exit loss, flow resistance of reducers and swages, etc., expressed in equivalent lengths of pipe.

# PUMP SELECTION GUIDE

CHART 3.3

| CLASS OF MECHANISM  |  | I. IMPELLOR  |                                      |                                      | II. CHAMBER-CRANK TRAIN                    |                                      | III. CHAMBER-WHEEL TRAIN             |                                      |                                      | IV. RECIPROCATING                    |                                      | V. MISCELLANEOUS                     |                                      |
|---|--|--|--------------------------------------|--------------------------------------|--|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| BASIC PUMP TYPE   |  | CENTRIFUGAL  | PROPELLOR                            | TURBINE                              | VANE                                       | NUTATOR                              | SPURGEAR                             | BEHRENS                              | SCREW                                | PISTON                               | DIAPHRAGM                            | MOYNO                                | PERISTALTIC                          |
| OTHER RELATED TYPES OF PUMP   |  | VOLUTE DIFFUSER  |                                      | AXIAL-FLOW TURBINE                   | CAM & PISTON, SHUTTLE-BLOCK, SWINGING VANE | NUTATING DISC                        | GEAR, STAR AND CRESCENT              |                                      | TRIPLE-SCREW                         | SWASH-PLATE, RADIAL, RAM             |                                      | 'SINGLE SCREW'                       |                                      |
| BASIC FORM OF MECHANISM, SHOWN SCHEMATICALLY (FLOW IS FROM LEFT TO RIGHT) |  |  |                                      |                                      |  |                                      |                                      |                                      |                                      |                                      |                                      |                                      |                                      |
| FLOW RATE AT CONSTANT DRIVE SPEED   |  | UNIFORM IF TOTAL HEAD UNCHANGED  |                                      |                                      | SOME VARIATION                             | UNIFORM AT CONSTANT DRIVE SPEED      |                                      |                                      |                                      | PULSATING UNDER ALL CONDITIONS       |                                      | UNIFORM                              | NEARLY UNIFORM                       |
| DISCHARGE PRESSURE  |  | LOW TO MEDIUM  |                                      |                                      | LOW TO HIGH                                | LOW TO MEDIUM                        | MEDIUM                               | LOW TO HIGH                          | MEDIUM                               | LOW TO HIGH                          | LOW TO HIGH                          | LOW TO MEDIUM                        | LOW                                  |
| TYPICAL FLUIDS HANDLED WITH APPROPRIATE CONSTRUCTION                      |  | CLEAN LIQUIDS<br>OILS<br>VISCIOUS LIQUIDS<br>SLURRIES<br>EMULSIONS<br>PASTES<br>LUMPS<br>POWDERS | ●<br>●<br>●<br>●<br>●<br>X<br>X<br>X | ●<br>●<br>X<br>●<br>●<br>X<br>X<br>X | ●<br>●<br>X<br>●<br>●<br>X<br>X<br>X       | ●<br>●<br>X<br>●<br>●<br>X<br>X<br>X | ●<br>●<br>X<br>●<br>●<br>X<br>X<br>X | ●<br>●<br>X<br>●<br>●<br>●<br>●<br>X | ●<br>●<br>X<br>●<br>●<br>●<br>X<br>X | ●<br>●<br>X<br>●<br>●<br>X<br>X<br>X | ●<br>●<br>●<br>●<br>●<br>X<br>X<br>X | ●<br>●<br>●<br>●<br>●<br>●<br>●<br>● | ●<br>●<br>●<br>●<br>●<br>●<br>X<br>X |
| ● = SUITABLE MECHANISM; X = MECHANISM EITHER UNSUITABLE OR NOT PREFERRED  |  |  |                                      |                                      |  |                                      |                                      |                                      |                                      |                                      |                                      |                                      |                                      |

## TYPES OF PUMP

A pump is a device for moving a fluid from one place to another thru pipes or channels. Chart 3.3, a selection guide for pumps, puts various types of pump used industrially into five catagories, based on operating principle. In common reference, the terms centrifugal, rotary, screw, and reciprocating are used. Chart 3.3 is not comprehensive: pumps utilizing other principles are in use. *About nine out of ten pumps used in industry are of the centri-fugal type.*

The following information is given to enable an estimate to be made of required total head, pump size, capacity, and horsepower for planning purposes. Data in the Guide permit estimating pump requirements *for water systems.*

## PUMP 'TOTAL HEAD'

A pump imparts energy to the pumped liquid. This energy is able to raise the liquid to a height, or 'head'. The 'total head' of a pump (in ft) is the energy (in ft-lb) imparted by the pump to each pound of liquid. In piped systems, part of the total head is used to overcome friction in the piping, which results in a pressure drop (or 'headloss').

For a centrifugal pump, the same total head can be imparted to all liquids of comparable viscosity, and is independent of the liquid's density: the required driving power increases with density. Figure 3.5 relates the total head provided by the pump to the headlosses in the pumped system.

## PRESSURE & 'HEAD'

In US customary units, pressure (  $p$  ) in PSI is related to head (  $h$  ) in ft:  $p \text{ [PSI]} = (d)(h)/(144) = (\text{S.G.})(h)/(2.31)$ , where  $d$  is liquid density in lb/ft<sup>3</sup>, and S.G. is specific gravity. Atmospheric pressure at sea level is equal to 14.7 PSIA, the pressure generated by a 34-ft height of water.

## VELOCITY HEAD

Usually the liquid being pumped is stationary before entering the suction piping, and some power is absorbed in accelerating it to the suction line velocity. This causes a small 'velocity head' loss (usually about 1 ft) and may be found from table 3.2, which is applicable to liquid of any density, if the velocity head is read as feet of the liquid concerned.

## VELOCITY & VELOCITY HEAD

TABLE 3.2

| VELOCITY (Ft/sec)  | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 12   | 15   |
|--------------------|------|------|------|------|------|------|------|------|------|
| VELOCITY HEAD (Ft) | 0.25 | 0.39 | 0.56 | 0.76 | 0.99 | 1.26 | 1.55 | 2.24 | 3.50 |

Flow rate, liquid velocity and cross-sectional area (at right angles to flow) are related by the formulas:

$$\text{Flow rate in cubic feet per second} = (\nu)(a)/(144)$$

$$\text{Flow rate in US gallons per minute} = (3.1169)(\nu)(a)$$

where:  $\nu$  = liquid velocity in feet per second

$a$  = cross-sectional area in square inches (table P-1)

## POWER CALCULATIONS

If S.G. = specific gravity of the pumped liquid,  $H$  = total head in feet of the pumped liquid, and  $p$  = pressure drop in PSI, then:

$$\text{Hydraulic horsepower} = \frac{(\text{GPM})(H)(\text{S.G.})}{3960} = \frac{(\text{GPM})(p)}{1714}$$

The mechanical efficiency,  $e$ , of a pump is defined as the hydraulic horsepower (power transferred to the pumped liquid) divided by the brake horsepower (power applied to the driving shaft of the pump).

If the pump is driven by an electric motor which has a mechanical efficiency  $e_m$ , the electricity demand is:

$$\text{Kilowatt (KW)} = \frac{(\text{GPM})(H)(\text{S.G.})}{(5310)(e)(e_m)} = \frac{(\text{GPM})(p)}{(2299)(e)(e_m)}$$

Often, estimates of brake horsepower, electricity demand, etc., must be made without proper knowledge of the efficiencies. To obtain estimates, the mechanical efficiency of a centrifugal pump may be assumed to be 60%, and that of an electric motor 80%.

## COMPRESSORS, BLOWERS & FANS

### 3.2.2

#### REFERENCES

'Compressed air and gas data'. Editor Gibbs C.W. (Ingersoll-Rand)  
'Air receivers'. Section 1910.169 of the Code of Federal Regulations; CFR  
Occupational Safety and Health Administration (OSHA)



Compressors are used to supply high-pressure air for plant use, to pressurize refrigerant vapors for cooling systems, to liquefy gases, etc. They are rated by their maximum output pressure and the number of cubic feet per minute of a gas handled at a specified speed or power, stated at 'standard conditions', 60 F and 14.7 PSIA (not at compressed volume). 60 F is accepted as standard temperature by the gas industry.

The term 'compressor' is usually reserved for machines developing high pressures in closed systems, and the terms 'blower' and 'fan' for machines working at low pressures in open-ended systems.

COMPRESSOR PRESSURE RANGES

TABLE 3.3

| MACHINE    | DISCHARGE PRESSURE RANGE          |
|------------|-----------------------------------|
| COMPRESSOR | 15 thru 20,000 PSIG, and higher   |
| BLOWER     | 1 thru 15 PSIG                    |
| FAN        | Up to 1 PSIG (about 30 in. water) |

#### COMPRESSING IN STAGES

Gases (including air) can be compressed in one or more operations termed 'stages'. Each stage can handle a practicable increase in pressure—before temperature increase due to the compression necessitates cooling the gas. Cooling between stages is effected by passing the gas thru an intercooler. Staging permits high pressures, and lower discharge temperatures, with reduced stresses on the compressor.

## TYPES OF COMPRESSOR

**RECIPROCATING COMPRESSOR** Air or other gas is pressurized in cylinders by reciprocating pistons. If the compressor is lubricated, the outflow may be contaminated by oil. If an oil-free outflow is required, the pistons may be fitted with graphite or teflon piston rings. Flow is pulsating.

**ROTARY SCREW COMPRESSOR** Air or other gas enters pockets formed between mating rotors and a casing wall. The pockets rotate away from the inlet, taking the gas toward the discharge end. The rotors do not touch each other or the casing wall. Outflow is uncontaminated in the 'dry type' of machine, in which power is applied to both rotors thru external timing gears. In the 'wet type', power is applied to one rotor, and both rotors are separated by an oil film, which contaminates the discharge. Flow is uniform.

**ROTARY VANE COMPRESSOR** resembles the rotary vane pump shown in chart 3.3. Variation in the volume enclosed by adjacent vanes as they rotate produces compression. Ample lubrication is required, which may introduce contamination. Flow is uniform.

**ROTARY LOBE COMPRESSOR** consists of two synchronized lobed rotors turning within a casing, in the same way as the pump shown in chart 3.3 (under 'spurgear' type). The rotors do not touch each other or the casing. No lubrication is used within the casing, and the outflow is not contaminated. Flow is uniform. This machine is often referred to as a 'blower'.

**DYNAMIC COMPRESSORS** resemble gas turbines acting in reverse. Both axial-flow machines and centrifugal machines (with radial flow) are available. Centrifugal compressors commonly have either one or two stages. Axial compressors have at least two stages, but seldom more than 16 stages. The outflow is not contaminated. Flow is uniform.

**LIQUID RING COMPRESSOR** This type of compressor consists of a single multi-bladed rotor which turns within a casing of approximately elliptic cross section. A controlled volume of liquid in the casing is thrown to the casing wall with rotation of the vanes. This liquid serves both to compress and to seal. Inlet and outlet ports located in the hub communicate with the pockets formed between the vanes and the liquid ring. These compressors have special advantages: wet gases and liquid carryover including hydrocarbons which are troublesome with other compressors are easily handled. Additional cooling is seldom required. Condensable vapor can be recovered by using liquid similar to that in the ring. Flow is uniform.

#### EQUIPMENT FOR COMPRESSORS

**INTERCOOLER** A heat exchanger used for cooling compressed gas between stages. Air must not be cooled below the dew point (at the higher pressure) as moisture will interfere with lubrication and cause wear in the next stage.

**AFTERCOOLER** A heat exchanger used for cooling gas after compression is completed. If air is being compressed, chilling permits removal of much of the moisture.

**DAMPENER or SNUBBER; VOLUME BOTTLE or SURGE DRUM** Reciprocating compressors create pulsations in the air or gas which may cause the

discharge and/or suction piping to resonate and damage the compressor or its valves. A dampener, or snubber, is a baffled vessel which smooths pulsations in flow. A volume bottle or surge drum has the same purpose, but lacks baffles. These devices are not normally part of the compressor package, and are often bought separately (with the compressor maker's recommendations). Large compressors may require an arrangement of 'choke tubes' (restrictions) and 'bottles' (vessels), conforming to a theoretical design and located near the compressor's outlet, upstream of the aftercooler.

The location of the following four items of equipment is shown in figure 6.23:

**SEPARATOR (normally used only with air compressors)** A water separator is often provided following the aftercooler, and, sometimes, also at the intake to a compressor having a long suction line, if water is likely to collect in the line. Each separator is provided with a drain to allow continuous removal of water.

**RECEIVER** Refer to 'Discharge (supply) lines' and 'Storing compressed air', this section.

**SILENCER** is used to suppress objectionable sound which may radiate from an air intake.

**FILTER** is provided in the suction line to an air compressor to collect particulate matter.

*The following information is given as a guide for engineering purposes*

#### LINE SIZES FOR AIR SUCTION & DISTRIBUTION

**SUCTION LINE** Suction lines and manifolds should be large enough to prevent excessive noise and starvation of the air supply. If the first compression stage is reciprocating, the suction line should allow a 10 to 23 ft/sec flow: if a single-stage reciprocating compressor is used, the intake flow should not be faster than 20 ft/sec. Dynamic compressors can operate with faster intake velocities, but 40 ft/sec is suggested as a maximum. The inlet reducer for a dynamic compressor should be placed close to the inlet nozzle.

**DISCHARGE (SUPPLY) LINES** are sized for 150 to 175% of average flow, depending on the number of outlets in use at any time. The pressure loss in a branch should be limited to 3 PSI. The pressure drop in a hose should not exceed 5 PSI. The pressure drop in distribution piping, from the compressor to the most remote part of the system, should not be greater than 5 PSI (not including hoses).

These suggested pressure drops may be used to select line sizes with the aid of table 3.5. From the required SCFM flow in the line to be sized, find the next higher flow in the table. Multiply the allowed pressure drop (PSI) in the line by 100 and divide by the length of the line in feet to obtain the PSI drop per 100 ft—find the next lower figure to this in the table, and read required line size.

Equipment drawing air at a high rate for a short period is best served by a receiver close to the point of maximum use—lines can then be sized on average demand. A minimum receiver size of double the SCF used in intermittent demand should limit the pressure drop at the end of the period of use to about 20% in the worst instances and keep it under 10% in most others.

COMPRESSOR CHARACTERISTICS

TABLE 3.4

| COMPRESSOR TYPE                               | MAXIMUM OUTPUT PRESSURE (PSIG) | CONTAMINANT IN OUTPUT | INFLOW (CFM/HP) | ECONOMIC RANGE (Inflow CFM)           |
|---|--------------------------------|-----------------------|-----------------|---------------------------------------|
|   |                                |                       |                 | DATA FOR 100 PSIG OUTFLOW             |
| RECIPROCATING<br>Lubricated<br>Non-lubricated | 35,000<br>700                  | OIL<br>NONE           | 4 to 7          | 10,000                                |
| DYNAMIC<br>Centrifugal<br>Axial               | 4,000<br>90                    | NONE<br>NONE          | 4<br>4½         | 500 to 110,000<br>5,000 to 13,000,000 |
| ROTARY VANE                                   | 125                            | OIL                   | 4               | 150 to 6,000                          |
| ROTARY LOBE                                   | 30                             | NONE                  |                 | 50,000                                |
| ROTARY SCREW<br>NON-LUBED/LUBED               | 125                            | NONE/<br>OIL          | 4               | 30 to 150                             |
| LIQUID RING                                   | 75*                            | WATER<br>or other     | 1.6 to 2.2      | 20 to 5,000                           |

\* Figure applies to a two-stage machine

**FLOW OF COMPRESSED AIR:  
PRESSURE DROPS OVER 100 Ft PIPE,  
WITH AIR ENTERING AT 100 PSIG\***  
(Adapted from data published by Ingersoll-Rand)

TABLE 3.5

| FREE AIR INFLOW<br>(SCFM) | NOMINAL PIPE SIZE (INCHES) – SCHEDULE 40 PIPE |      |   |      |      |      |  |      |      |
|---------------------------|---|------|---|------|------|------|--|------|------|
|                           | ¾   | 1    | 1½  | 2    | 2½   | 3    | 4  | 6    |      |
| 40                        | 1.24  | 0.37 | Pressure drop smaller than<br>than 0.1 PSI per 100 ft |      |      |      |  |      |      |
| 70                        | 3.77  | 1.05 |   |      |      |      |  |      | 0.12 |
| 90                        | 6.00  | 1.69 |   |      |      |      |  |      | 0.19 |
| 100                       | 7.53  | 2.09 |   |      |      |      |  |      | 0.24 |
| 400                       |   | 32.2 | 3.59  | 0.98 | 0.41 | 0.13 | Pressure drop larger<br>than 35 PSI per 100 ft |      |      |
| 700                       |   |      | 10.8  | 2.92 | 1.19 | 0.38 |  |      | 0.10 |
| 900                       |   |      | 17.9  | 4.78 | 1.97 | 0.62 |  |      | 0.15 |
| 1,000                     |   |      | 22.0  | 5.90 | 2.43 | 0.76 |  |      | 0.19 |
| 4,000                     |   |      |   |      |      | 11.9 | 2.90   | 0.35 |      |
| 7,000                     |   |      |   |      |      |      | 8.77   | 1.06 |      |
| 9,000                     |   |      |   |      |      |      | 14.6   | 1.75 |      |
| 10,000                    |   |      |   |      |      |      | 18.0   | 2.13 |      |
| 40,000                    |   |      |   |      |      |      |  | 33.8 |      |

\*Pressure drop varies inversely as absolute pressure of entering air.

#### POWER CONSUMPTION

The power consumption of the different compressor types is characteristic. Table 3.4 gives the horsepower needed at an output pressure of 100 PSIG. Power consumption per CFM rises with rising output pressure. Air cooling adds 3-5% to power consumption (including fan drive). 'FAD' power consumption figures for compressors of 'average' power consumption are given. 'FAD' denotes 'free air delivered corresponding to standard cubic ft per minute (SCFM) or liters per minute measured as set out in ASME PTC9, BS 1571 or DIN 1945.'

# SPECIFIC POWER CONSUMPTION (FAD)

| P S I G               |              | 50 | 75 | 100 | 125 |
|-----------------------|--------------|----|----|-----|-----|
| HP per 100 CFM INFLOW | SINGLE-STAGE | 14 | 18 | 22  | 24  |
|                       | TWO-STAGE    | 13 | 16 | 18  | 21  |

## COOLING-WATER REQUIREMENTS

Cooling-water demand is normally shown on the vendor's P&ID or data sheet. Most of the water demand is for the aftercooler (and intercooler, with a two-stage compressor). Jackets and lube oil may also require cooling. As a guide, 8 US gallons per hour are needed for each horsepower supplied to the compressor. If the final compression is 100 PSIG, the water demand will usually be about 2 US GPH per each SCFM inflow. These approximate demands are based on an 40 F temperature increase of the cooling water. Demand for cooling water increases slightly with relative humidity of the incoming air.

## QUANTITIES OF MOISTURE CONDENSED FROM COMPRESSED AIR

The following calculation (taken from the referenced Atlas Copco manual) is for a two-stage compressor, and is based on moisture content given in the table below:

### DATA:

Capacity of the compressor = 2225 SCFM

Temperature of the incoming air = 86 F

Relative humidity of the incoming air = 75%

Intercooler { Outlet temperature = 86 F  
Air pressure = 25.3 PSIG, or 40 PSIA  
Water separation efficiency = 80%

Aftercooler { Outlet air temperature = 86 F  
Air pressure = 100 PSIG, or 115 PSIA  
Water separation efficiency = 90%

### CALCULATIONS:

- From the table, weight of water vapor in 2225 SCFM air at 86 F and 75% RH =  $(0.00189)(2225)(0.75) = 3.15$  lb/min.
- Rate of removal of condensed water from intercooler, thru trap =  $(0.8)[3.15 - (0.00189)(2225)(14.7)/(40)] = 1.28$  lb/min., or  $(1.28)(60)/(8.33) = 9.2$  US GPH
- Rate of removal of condensed water from aftercooler, thru trap =  $(0.9)[3.15 - 1.28 - (0.00189)(2225)(14.7)/(115)] = 1.20$  lb/min., or  $(1.20)(60)/(8.33) = 8.6$  US GPH
- Total rate at which water is removed from both coolers =  $9.2 + 8.6 = 17.8$  US GPH

## MOISTURE CONTENT OF AIR AT 100% RH

| TEMPERATURE<br>(Degrees F)                         | 14   | 32   | 50   | 68   | 86   | 104  | 122  |
|--|------|------|------|------|------|------|------|
| MOISTURE<br>(10 <sup>-4</sup> lb/ft <sup>3</sup> ) | 1.35 | 3.02 | 5.87 | 10.9 | 18.9 | 31.6 | 51.3 |

## UNLOADING (POSITIVE-DISPLACEMENT COMPRESSORS)

'Unloading' is the removal of the compression load from the running compressor. Compressors are unloaded at startup and for short periods when demand for gas falls off. Damage to the compressor's drive motor can result if full compression duties are applied suddenly.

If the vendor does not provide means of unloading the compressor, a manual or automatic bypass line should be provided between suction and discharge (on the compressor's side of any isolating valves)—see figure 6.23.

Provision should be made so that the discharge pressure cannot rise above a value which would damage the compressor or its driver. Automatic unloading will ensure this, and the control actions are listed in table 3.6.

### AUTOMATIC UNLOADING ACTIONS FOR COMPRESSORS

TABLE 3.6

| COMPRESSOR  | DISCHARGE PRESSURE  | AUTOMATIC CONTROL ACTION  |
|-------------|---|---|
| Not running | Low—reaches lower set value                                 | Starts compressor unloaded, accelerates to normal speed, and brings on load |
| Running     | High—reaches higher set value                               | Unloads compressor for a preset period                                      |
| Idling      | Low—reaches reload pressure before idling period is over    | Reloads compressor  |
|             | Medium—idling period ends before reload pressure is reached | Switches off compressor   |

## STORING COMPRESSED AIR

A limited amount of compressed air or other gas can be stored in receivers. One or more receivers provided in the compressor's discharge piping also serve to suppress surges (which can be due to demand, as well as supply) to assist cooling, and to collect moisture. Receivers storing air or other gas are classed as pressure vessels—refer to 6.5.1.

**RECEIVER CONSTRUCTION** Usual construction is a long vertical cylinder with dished heads, supported on a pad. Water will collect in the base, and therefor a valved drain must be provided for manual blowdown. Collected water may freeze in cold climates. Feeding the warm air or gas at the base of the receiver may prevent freezing, but the inlet must be designed so that it cannot be closed by water if it does freeze.

**CAPACITY NEEDED** A simple rule to decide the total receiver volume is to divide the compressor rating in SCFM by ten to get the volume in cubic feet for the receiver. For example, if the compressor is designed to take 5500 cubic feet per minute, a receiver volume of about 550 cubic feet is adequate. This rule is considered suitable for outflow pressures up to about 125 PSIG and where the continuously running compressor is unloaded by automatic valves—see 'Unloading' above. An extensive piping system for distributing compressed air or other gas may have a capacity sufficiently large in itself to serve as a receiver.

## PROCESS EQUIPMENT

### 3.3

Process equipment is a term used to cover the many types of equipment used to perform one or more of these basic operations on the process material:

- (1) **CHEMICAL REACTION**
- (2) **MIXING**
- (3) **SEPARATION**
- (4) **CHANGE OF PARTICLE SIZE**
- (5) **HEAT TRANSFER**

Equipment manufacturers give all information necessary for installation and piping.

This section is a quick reference to the function of some items of equipment used in processwork. In table 3.7, the function of the equipment is expressed in terms of the phase (solid, liquid or gas) of the process materials mixed. Examples: (1) A blender can mix two powders, and its function is tabulated as "S+S". (2) An agitator can be used to stir a liquid into another liquid—this function is tabulated "L+L". Another large and varied group of equipment achieves separations, and a similar method of tabulating function is used in table 3.8.

### CHEMICAL REACTION

#### 3.3.1

Chemical reactions are carried out in a wide variety of specialized equipment, termed reactors, autoclaves, furnaces, etc. Reactions involving liquids, suspensions, and sometimes gases, are often performed in 'reaction vessels'. The vessel and its contents frequently have to be heated or cooled, and piping to a jacket or internal system of coils has to be arranged. If reaction takes place under pressure, the vessel may need to comply with the ASME Boiler and Pressure Vessel Code. Refer also to 6.5.1, under 'Pressure vessels', and to the standards listed in table 7.10.

### MIXING

#### 3.3.2

A variety of equipment is made for mixing operations. The principal types of equipment are listed in table 3.7:

#### MIXING EQUIPMENT

TABLE 3.7

| EQUIPMENT                             | PHASES MIXED        |
|---------------------------------------|---------------------|
| AGITATOR                              | S + L, L + L        |
| BLENDER (TUMBLER TYPE)                | S + S, S + L        |
| EDUCTOR                               | L + L, L + G, G + G |
| MIXER (RIBBON, SCROLL, OR OTHER TYPE) | S + S, S + L        |
| PROPORTIONING PUMP                    | L + L               |
| PROPORTIONING VALVE                   | L + L               |
| (G = GAS, L = LIQUID, S = SOLID)      |                     |

## SEPARATION

### 3.3.3

Equipment for separation is even more varied. Equipment separating solids on the basis of particle size or specific gravity alone are in general termed classifiers. The broader range of separation equipment separates phases (solid, liquid, gas) and some of the types used are listed in the table below:

#### SEPARATION EQUIPMENT

TABLE 3.8

| EQUIPMENT  | FEED MATERIAL                | RETAINED MATERIAL  | OUTFLOW MATERIAL            |
|--|------------------------------|--------------------|-----------------------------|
| CENTRIFUGE   | S + L                        | S                  | L                           |
| CONTINUOUS CENTRIFUGE  | L(1) + L(2)                  | None               | L(1), L(2), †               |
| CYCLONE  | S + G                        | None               | G, S †                      |
| DEAERATOR  | L + G                        | L                  | G                           |
| DEFOAMER   | L + G                        | L                  | G                           |
| DISTILLATION COLUMN  | L(1) + L(2)                  | L(1)               | L(2) *                      |
| DRYER  | S + L                        | S                  | L *                         |
| DRY SCREEN   | S(1) + S(2)                  | S(1)               | S(2)                        |
| EVAPORATOR   | L + S                        | L + S              | L *                         |
|  | L(1) + L(2)                  | L(1)               | L(2) *                      |
| FILTER PRESS   | S + L                        | S                  | L                           |
| FLOTATION TANK   | S + L                        | S                  | L                           |
| FRACTIONATION COLUMN   | L(1) + L(2)<br>+ L(3) + etc. | None               | L(1), L(2),<br>L(3), etc. † |
| SCRUBBER   | S + G                        | S                  | G                           |
| SETTLING TANK  | S + L                        | S                  | L                           |
| STRIPPER   | L(1) + L(2)                  | L(1)               | L(2)                        |
| † Separate flows   |                              | * Removed as vapor |                             |
| (G = GAS, L = LIQUID, S = SOLID, S(1), S(2), L(1), L(2), etc. = DIFFERENT SOLIDS OR LIQUIDS) |                              |                    |                             |

### CHANGE OF PARTICLE SIZE

#### 3.3.4

Reduction of particle size is a common operation, and can be termed 'attrition'. Equipment used includes crushers, rod-, ball- and hammer-mills, and—to achieve the finest reductions—energy mills, which run on compressed air. Emulsions ('creams' or 'milks'), which are liquid-in-liquid dispersions, are stabilized by homogenizers, typically used on milk to reduce the size of the fat globules and thus prevent cream from separating.

Occasionally, particle or lump size of the product is increased. Equipment for agglomerating, pelletizing, etc., is used. Examples: tablets, sugar cubes, powdered beverage and food products.

### PROCESS HEAT TRANSFER

#### 3.3.5

Adding and removing heat is a significant part of chemical processing. Heating or cooling of process material is accomplished with heat exchangers, jacketed vessels, or other heat transfer equipment. The project and piping groups specify the duty and mechanical arrangement, but the detail design is normally left to the manufacturer.

The term 'heat exchanger' in chemical processing refers to an unfired vessel exchanging heat between two fluids which are kept separated. The commonest form of heat exchanger is the 'shell-and-tube' exchanger, consisting of a bundle of tubes held inside a 'shell' (the vessel part). One fluid passes inside the tubes, the other thru the space between the tubes and shell. Exchanged heat has to flow thru the tube walls. Refer to 6.8 ('Keeping process material at the right temperature') and to 6.6 for piping shell-and-tube heat exchangers.

Heat exchange with process material can take place in a variety of other equipment, such as condensers, evaporators, heaters, chillers, etc.

### **MULTIFUNCTION EQUIPMENT**

### **3.3.6**

Sometimes, items of equipment are designed to perform more than one of the functions listed at the beginning of 3.3.

Mixing and heating (or cooling) may be simultaneously carried out in mixers having blades provided with internal channels to carry hot (or cold) fluid.

Separation and attrition may be achieved in a single mill, designed to output particles of the required degree of fineness and recycle and regrind particles which are still too coarse.

.....  
■

# ORGANIZATION OF WORK : Job Responsibilities, Drawing-Office Equipment and Procedures

## THE PIPING GROUP

### 4.1

Plant design is divided into several areas, each the responsibility of a 'design group'. Chart 4.1(a) shows the main groups of people cooperating on the plant design, and the types of drawings for which they are responsible. Other groups, involved with instrumentation, stress analysis, pipesupport, etc., contribute to the design at appropriate stages.

The personnel responsible for the piping design may be part of an engineering department's mechanical design group, or they may function as a separate section or department. For simplicity, this design group is referred to as the 'piping group', and its relationship with the organization and basic activities are indicated in chart 4.1(a).

Chart 4.1(c) shows the structure of a design group.

### RESPONSIBILITIES OF THE PIPING GROUP

#### 4.1.1

The piping group produces designs in the form of drawings and model(s), showing equipment and piping.

The following are provided by the piping group as its contribution to the plant design:—

- (1) **AN EQUIPMENT ARRANGEMENT DRAWING, USUALLY TERMED THE 'PLOT PLAN'**
- (2) **PIPING DESIGN (DRAWINGS OR MODEL)**
- (3) **PIPING DETAILS FOR FABRICATION AND CONSTRUCTION**
- (4) **REQUISITIONS FOR PURCHASE OF PIPING MATERIEL**

### JOB FUNCTIONS

#### 4.1.2

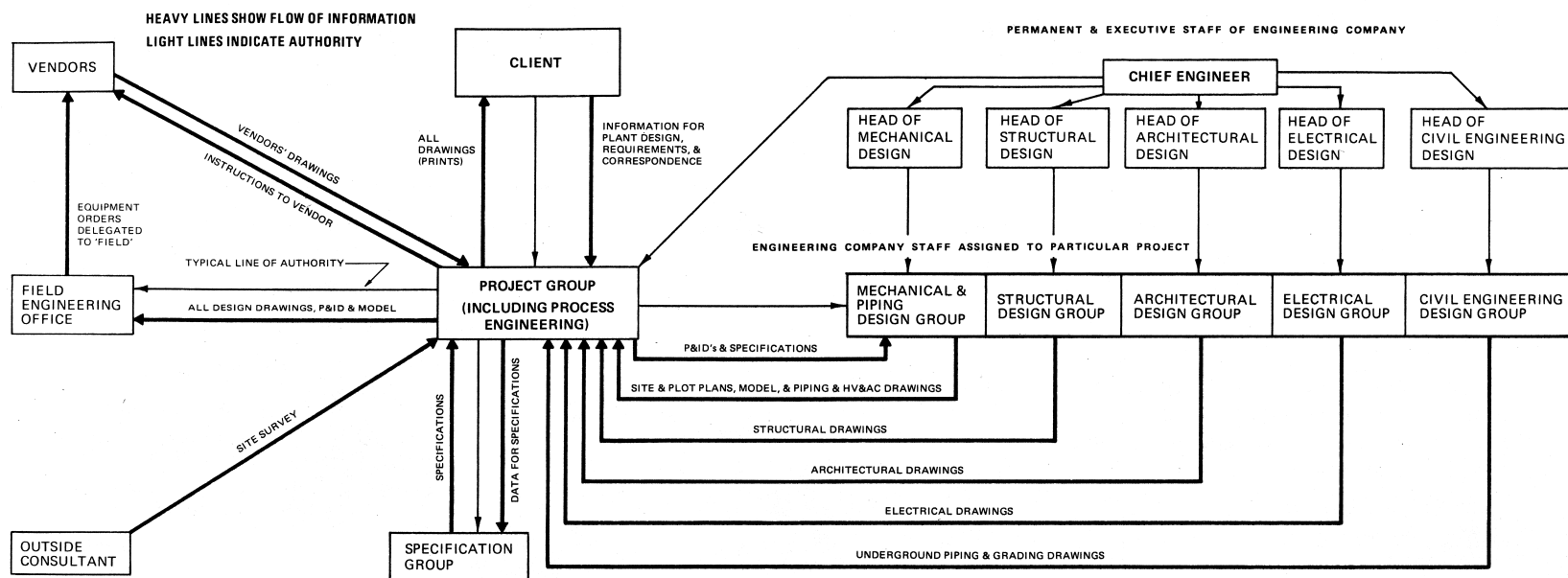
On joining a design office it is important that the new member should know what line of authority exists. This is especially important when information is required and it saves the wrong people from being interrupted. Chart 4.2 shows two typical lines of authority. (Different companies will have different set-ups and job titles.)

| JOB   | FUNCTIONS   |
|---|---|
| <b>DESIGN SUPERVISOR</b>  | <ol style="list-style-type: none"> <li>(1) RESPONSIBLE FOR ALL PERSONNEL IN GROUPS INCLUDING HIRING</li> <li>(2) COORDINATING WITH OTHER GROUPS (AND THE CLIENT)</li> <li>(3) OVERALL PLANNING AND SUPERVISING THE GROUP'S WORK</li> <li>(4) LIAISON WITH PROJECT ENGINEER(S)</li> </ol>  |
| <b>GROUP LEADER</b><br><b>NOTE: On small projects, may also assume Design Supervisor's duties</b> | <ol style="list-style-type: none"> <li>(1) SUPERVISING DESIGN &amp; DRAFTING IN AREA(S) ALLOCATED BY DESIGN SUPERVISOR</li> <li>(2) ASSIGNING WORK TO DESIGNERS &amp; DRAFTERS</li> <li>(3) RESPONSIBLE FOR PLOT PLANS, PLANT DESIGNS &amp; PRESENTATION &amp; COMPLETENESS OF FINISHED DRAWINGS</li> <li>(4) COORDINATES MECHANICAL, STRUCTURAL, ELECTRICAL, AND CIVIL DETAILS FROM OTHER GROUPS</li> <li>(5) CHECKING &amp; MARKING VENDORS' DRAWINGS</li> <li>(6) OBTAINING INFORMATION FOR MEMBERS OF THE GROUP</li> <li>(7) ESTABLISHING THE NUMBER OF DRAWINGS REQUIRED FOR EACH JOB (DRAWING CONTROL OR REGISTER)—SEE INDEX</li> <li>(8) ASSIGNING TITLES FOR EACH DRAWING AND MAINTAINING UP-TO-DATE DRAWING CONTROL OR REGISTER OF DRAWINGS, CHARTS, GRAPHS, AND SKETCHES FOR EACH CURRENT PROJECT</li> <li>(9) ESTABLISHING A DESIGN GROUP FILING SYSTEM FOR ALL INCOMING &amp; OUTGOING PAPERWORK</li> <li>(10) KEEPING A CURRENT SCHEDULE AND RECORD OF HOURS WORKED</li> <li>(11) REQUISITIONING VIA PURCHASING DEPARTMENT ALL PIPING MATERIALS</li> </ol> |
| <b>CHECKER</b>  | <ol style="list-style-type: none"> <li>(1) CHECKING DESIGNERS' AND DRAFTERS' DESIGNS AND DETAILS FOR DIMENSIONAL ACCURACY AND CONFORMITY WITH SPECIFICATIONS, P&amp;ID's, VENDORS' DRAWINGS, ETC.</li> <li>(2) IF AGREED WITH THE DESIGNER &amp;/OR GROUP LEADER, MAY MAKE IMPROVEMENTS AND ALTERATIONS TO THE DESIGN</li> </ol>  |
| <b>DESIGNER</b>   | <ol style="list-style-type: none"> <li>(1) PRODUCING STUDIES AND LAYOUTS OF EQUIPMENT AND PIPING WHICH MUST BE ECONOMIC, SAFE, OPERABLE AND EASILY MAINTAINED</li> <li>(2) MAKING ANY NECESSARY ADDITIONAL CALCULATIONS FOR THE DESIGN</li> <li>(3) SUPERVISING DRAFTERS</li> </ol>   |
| <b>DRAFTER</b>  | <p>MINIMUM RESPONSIBILITIES ARE:—</p> <ol style="list-style-type: none"> <li>(1) PRODUCING DETAILED DRAWINGS FROM DESIGNERS' OR GROUP LEADERS' STUDIES OR SKETCHES</li> <li>(2) SECONDARY DESIGN WORK</li> <li>(3) FAMILIARIZATION WITH THE RECORDS, FILES, INFORMATION SHEETS AND COMPANY PRACTICES RELATING TO THE PROJECT</li> </ol>   |

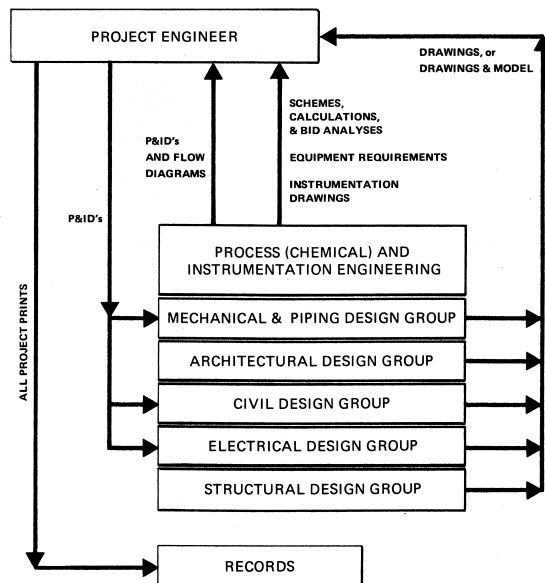
# OFFICE ORGANIZATION

## CHART 4.1

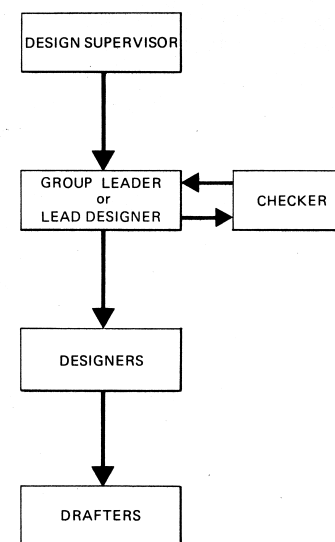
### (a) PROJECT ORGANIZATION



### (b) PROJECT & DESIGN GROUPS SHOWING FLOW OF INFORMATION



### (c) DESIGN GROUP SHOWING LINES OF AUTHORITY



DESIGN INFORMATION TO PIPING GROUP4.2

The following information is required by the piping group:—

|                           |     |   |
|---------------------------|-----|---|
| FROM THE<br>PROJECT GROUP | (1) | 'JOB SCOPE' DOCUMENT, WHICH DEFINES PROCEDURES TO BE USED IN PREPARING DESIGN SKETCHES AND DIAGRAMS |
|                           | (2) | PIPING & INSTRUMENTATION DIAGRAM (P&ID—SEE 5.2.4)   |
|                           | (3) | LIST OF MAJOR EQUIPMENT (EQUIPMENT INDEX), SPECIAL EQUIPMENT AND MATERIALS OF FABRICATION           |
|                           | (4) | LINE DESIGNATION SHEETS OR TABLES, INCLUDING ASSIGNATION OF LINE NUMBERS—SEE 4.2.3 AND 5.2.5        |
|                           | (5) | SPECIFICATIONS FOR MATERIALS USED IN PIPING SYSTEMS—SEE 4.2.1                                       |
|                           | (6) | SCHEDULE OF COMPLETION DATES (UPDATED ON FED-BACK INFORMATION)                                      |
|                           | (7) | CONTROLS (METHODS OF WORKING,ETC.) TO BE ADOPTED FOR EXPEDITING THE JOB                             |
| FROM OTHER GROUPS         | (8) | DRAWINGS—SEE 5.2.7  |
| FROM SUPPLIERS            | (9) | VENDORS' PRINTS—SEE 5.2.7   |

SPECIFICATIONS4.2.1

These consist of separate specifications for plant layout, piping materials, supporting, fabrication, insulation, welding, erection, painting and testing. The piping designer is mostly concerned with plant layout and materiel specifications, which detail the design requirements and materials for pipe, flanges, fittings, valves, etc., to be used for the particular project.

The piping materials specification usually has an index to the various services or processes. The part of the specification dealing with a particular service can be identified from the piping drawing line number or P&ID line number—see 5.2.4 under 'Flow lines'. All piping specifications must be strictly adhered to as they are compiled from information supplied by the project group. Although the fittings, etc., described in the Guide are those most frequently used, they will not necessarily be seen in every piping specification.

On some projects (such as 'revamp' work) where there is no specification, the designer may be responsible for selecting materials and hardware, and it is important to give sufficient information to specify the hardware in all essential details. Non-standard items are often listed by the item number and/or model specification for ordering taken from the catalog of the particular manufacturer.

LIST OF EQUIPMENT, or EQUIPMENT INDEX4.2.2

This shows, for each item of equipment, the equipment number, equipment title, and status—that is whether the item has been approved, ordered, and whether certified vendor's prints have been received.

LINE DESIGNATION SHEETS, or TABLES4.2.3

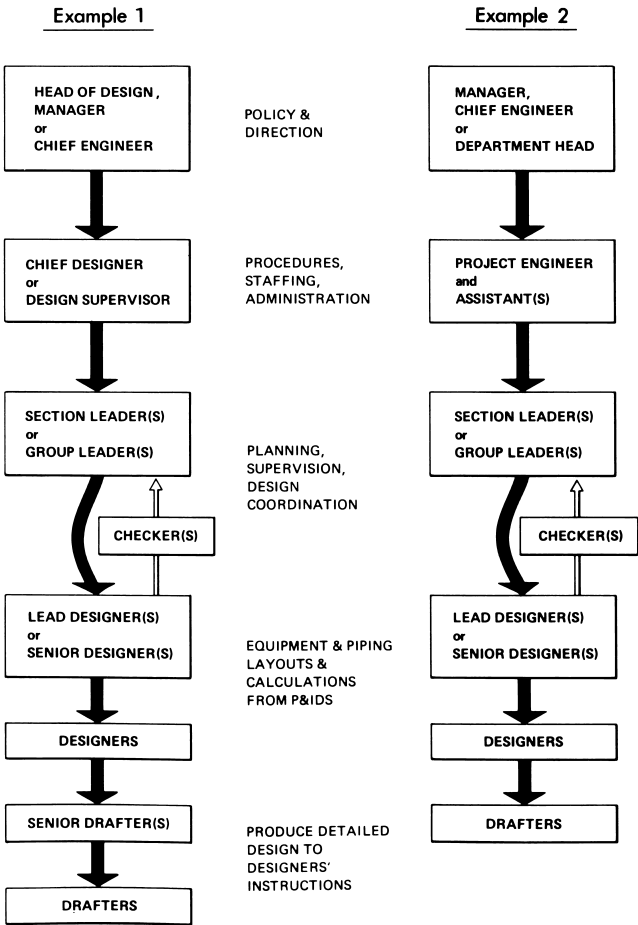
These sheets contain tabulated data showing nominal pipe size, material specification, design and operating conditions. Line numbers are assigned in sequence of flow, and a separate sheet is prepared for each conveyed fluid —see 5.2.5.

DRAWING CONTROL (REGISTER)4.2.4

A drawing number relates the drawing to the project, and may be coded to show such information as project (or 'job') number, area of plant, and originating group (which may be indicated 'M' for mechanical, etc.). Figure 5.15 shows a number identifying part of a piping system.

The drawing control shows the drawing number, title, and progress toward completion. The status of revision and issues is shown—see 5.4.3. The drawing control is kept up-to-date by the group leader.

DESIGN GROUP—TWO TYPICAL LINES OF AUTHORITYCHART 4.2



## FILING DRAWINGS

### 4.3

There are two types of drawings to file—those produced by the group and those received by the group. The former are filed in numerical order under plant or unit number in the drawing office on a 'stick file' or in a drawer—see 4.4.10. The filing of the latter, 'foreign', prints is often poorly done, causing time to be wasted and information to be lost. These prints are commonly filed by equipment index number, placing all information connected with that item of equipment in the one file.

A suggested method for filing these incoming prints is illustrated in chart 4.3, which cross-references process, function, or area with the group originating the drawing, and with associated vessels, equipment, etc. All correspondence between the project and design groups, client, vendors, and field would be filed under 'zero', as shown.

## MATERIALS & TOOLS FOR THE DRAFTING ROOM

### 4.4

### PAPER

#### 4.4.1

Vellum paper and mylar film are used for drawings. Drawing sheets must be translucent to the light used in copying machines. Mylar with a coated drawing surface is more expensive than vellum, but is preferable where durability and dimensional stability are important. Sheets can be supplied printed with border and title block and with a 'fade-out' ruled grid on the reverse side. 'Isometric' sheets with fade-out 30-degree grid are available for drawing isos.

ANSI 14.1 defines the following flat drawing-sheet sizes (in inches): (A) 8½x11, (B) 11x17, (C) 17x22, (D) 22x34, (E) 34x44.

International drawing sheet sizes of approximately the same dimensions are defined (in inches) as: (A4) 8.27x11.69, (A3) 11.69x16.54, (A2) 16.54x23.39, (A1) 23.39x33.11, (A0) 33.11x46.81.

**PAPERS FOR COPYING MACHINES** Photosensitive paper is used for making prints for checking, issuing and filing purposes. 'Sepia' photocopying paper (Ozalid Company, etc.) gives brown positive prints which may be amended with pencil or ink, and the revision used as an original for photocopying in a diazo machine. Sepias may also be used to give a faint background print for drawing other work over, such as ducting or pipe supports. The quality of sepia prints is not good. Positive photocopies of superior quality are made on clear plastic film, which may have either continuous emulsion to give heavy copies, or screened emulsion to yield faint background prints (emulsion should preferably be water-removable).

### LEADS & PENCILS

#### 4.4.2

Pencil leads used in the drawing office are available in the following grades, beginning with the softest : B (used for shading), HB (usually used for writing only), F (usually softest grade used for drafting), H (grade most often used for drafting), 2H (used for drawing thinner lines such as dimension lines), 3H and 4H (used for faint lines for layout or background). Softer penciling is prone

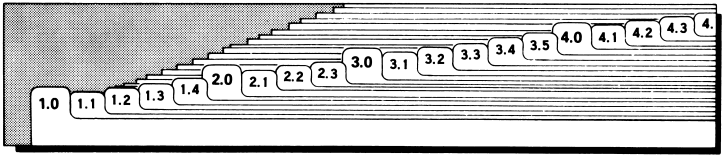
## FILING SYSTEM

### CHART 4.3

|    | UNIT OR AREA               |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
|----|----------------------------|------------|--------|------------|-------|------------|---------------|-----------------|-------|---------|-------|------------|------------|------------|----------|-----|-----|--|
|    | CORRESPONDENCE             | MECHANICAL | PIPING | ELECTRICAL | CIVIL | STRUCTURAL | ARCHITECTURAL | INSTRUMENTATION | PUMPS | VESSELS | TANKS | EXCHANGERS | CONDENSERS | SEPARATORS | CONVEYOR |     |     |  |
| 1  | .0                         | .1         | .2     | .3         | .4    | .5         | .6            | .7              | .8    | .9      | .10   | .11        | .12        | .13        | .14      | .15 | .16 |  |
| 2  | COMPRESSED AIR             |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
| 3  | COOLING WATER              |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
| 4  | FLARESTACK                 |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
| 5  | FUEL OIL                   |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
| 6  | SOLVENTS                   |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
| 7  | STEAM SYSTEM               |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
| 8  | VENTILATION – OFFICES      |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
| 9  | VENTILATION – PROCESS AREA |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
| 10 |                            |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |
|    |                            |            |        |            |       |            |               |                 |       |         |       |            |            |            |          |     |     |  |

Paperwork classified according to a system of this type may be located in a filing cabinet fitted with numbered dividers as shown :—

### STANDARD DIVIDERS FOR FILING CABINET



to smearing on handling, Grades harder than 3H tend to cut paper making lines difficult to erase. Conventional leads are 2 mm in diameter and require frequent repointing. 0.5 mm and 0.3 mm leads speed work, as they need no repointing. Conventional leads are not suitable for use on plastic films as they smear and are difficult to erase. 'Film' leads and pencils are available in the same sizes as conventional leads, and in different grades of hardness.

Clutch pencils (lead holders) suitable for use with either type of the smaller diameter leads have a push-button advance.

### SCALES

#### 4.4.3

The architect's scale is used for piping drawings, and is divided into fractions of an inch to one foot—for example, 3/8 inch per foot. The engineer's scale is used to draw site plans, etc., and is divided into one inch per stated number of feet, such as 1 inch per 30 feet.

**ERASERS & ERASING SHIELDS** **4.4.4**

Several types of eraser and erasing methods are available—use of each is given in table 4.1: Rubber in various hardnesses from pure gum rubber (artgum) for soft pencilling and cleaning lead smears, to hard rubber for hard pencilling and ink; ‘plastic’ is cleaner to use, as it has less tendency to absorb graphite; ‘magic rub’ for erasing pencil from plastic films. Most types of eraser are available for use with electric erasing machines.

An erasing shield is a thin metal plate with holes of various shapes and sizes so that parts of the drawing not to be erased may be protected.

**ERASING GUIDE** **TABLE 4.1**

| MATERIAL   | MEDIUM | SOFT PENCIL    | HARD PENCIL | INDIAN INK       | PHOTOGRAPHIC BACKGROUND |
|--|--------|----------------|-------------|------------------|-------------------------|
| TRACING PAPER, or LINEN  |        | SRE, or artgum | HRE, or SRE | IHRE             | _____                   |
| SEPIA (OZALID), or PHOTOCOPY PAPER (PHOTOSTAT)   |        | SRE            | HRE, or SRE | Blade, or IHRE   | Bleach *                |
| PLASTIC FILM   |        | Wet PE         | Wet PE      | Wet PE, or Blade | Wet PE, or Bleach*      |
| KEY: E = eraser. SR = soft rubber, HR = hard rubber, I = ink, P = plastic.<br>* Chemical bleach for removing black photographic silver deposit |        |                |             |                  |                         |

**CLEANING POWDER** **4.4.5**

Fine rubber granules are supplied in ‘salt-shaker’ drums. Sprinkled on a drawing, these granules reduce smearing of pencil lines during working. The use of cleaning powder is especially helpful when using a teesquare. The powder is brushed off after use.

**LETTERING AIDS** **4.4.6**

Title blocks, notes, and subtitles on drawings or sections should be in capitals. Capitals, either upright or sloped, are preferred. Pencilled lettering is normally used. Where ink work is required on drawings for photography, charts, reports, etc., ink stylus pens (Technos, Rapidograph, etc.) are available for stencil lettering (and for line drawing in place of ruling pens). The Leroy equipment is also used for inked lettering. Skeleton lettering templates are used for lettering section keys. The parallel line spacer is a small, inexpensive tool useful for ruling guide lines for lettering.

As alternatives to hand-inked lettering, machines such as Kroy which print onto adhesive-backed transparent film which is later positioned on the drawing. Adhesive or transferable letters and numbers are available in sheets, and special patterns and panels can be supplied to order for title blocks or detailing, symbolism, abbreviations, special notes, etc. Printed adhesive tapes

are limited in application, but are useful for making drawings for photographic reproduction, such as panel boards, charts, and special reports—see 4.4.13, under ‘Photographic layouts’.

**TEMPLATES** **4.4.7**

Templates having circular and rectangular openings are common. Orthogonal and isometric drafting templates are available for making process piping drawings and flow diagrams. These piping templates give the outlines for ANSI valves, flanges, fittings and pipe diameters to 3/8 inch per foot, or 1/4-inch per foot.

**MACHINES** **4.4.8**

The first two machines are usually used in drawing offices in place of the slower teesquare:

**DRAFTING MACHINE** allows parallel movement of a pair of rules set at right angles. The rules are set on a protractor, and their angle on the board may be altered. The protractor usually has 15-degree clickstops and vernier scale.

**PARALLEL RULE, or SLIDER**, permits drawing of long horizontal lines only, and is used with a fixed or adjustable triangle.

**PLANIMETER** A portable machine for measuring areas. When set to the scale of the drawing, the planimeter will measure areas of any shape.

**PANTOGRAPH** System of articulated rods permitting reduction or enlargement of a drawing by hand. Application is limited.

**LIGHT BOX** **4.4.9**

A light box has a translucent glass or plastic working surface fitted underneath with electric lights. The drawing to be traced is placed on the illuminated surface.

**FILING METHODS** **4.4.10**

Original drawings are best filed flat in shallow drawers. Prints filed in the drawing office are usually retained on a ‘stick’, which is a clamp for holding several sheets. Sticks are housed in a special rack or cabinet.

Original drawings will eventually create a storage problem, as it is inadvisable to scrap them. If these drawings are not sent to an archive, after a period of about three years they are photographed to a reduced scale for filing, and only the film is retained. Equipment is available for reading such films, or large photographic prints can be made.

## COPYING PROCESSES

### 4.4.11

'Diaz' or 'dyeline' processes reproduce to the same scale as the original drawing as a positive copy or print. Bruning and Ozalid machines are often employed. The drawing that is to be copied must be on tracing paper, linen or film, and the copy is made on light-sensitive papers or films. The older reversed-tone 'blue-print' is no longer in use.

## SCALED PLANT MODELS

### 4.4.12

Plant models are often used in designing large installations involving much piping. When design of the plant is completed, the model is sent to the site as the basis of construction in the place of orthographic drawings. Some engineering companies strongly advocate their use, which necessitates maintaining a model shop and retaining trained personnel. Scaled model piping components are available in a wide range of sizes. The following color coding may be used on models:—

|                       |                     |
|-----------------------|---------------------|
| PIPING . . . . .      | YELLOW, RED or BLUE |
| EQUIPMENT . . . . .   | GREY                |
| INSTRUMENTS . . . . . | ORANGE              |
| ELECTRICAL . . . . .  | GREEN               |

## ADVANTAGES

- Available routes for piping are easily seen
- Interferences are easily avoided
- Piping plan and elevation drawings can be eliminated; only the model, plot plan, P&ID's, and piping fabrication drawings (isos) are required
- The model can be photographed — see 4.4.13.
- Provides a superior visual aid for conferences, for construction crews and for training plant personnel

## DISADVANTAGES

- Duplication of the model is expensive
- The model is not easily portable and is liable to damage during transportation
- Changes are not recorded in the model itself

## PHOTOGRAPHIC AIDS

### 4.4.13

### 'DRAWINGS' FROM THE MODEL

The lack of portability of a scaled plant model can be partially overcome by photographing it. To do this it must be designed so that it can be taken apart easily. Photographs can be made to correspond closely to the regular plan, elevation and isometric projections by photographing the model from 40 ft or more away with long focal length lenses—'vanishing points' (converging lines) in the picture are effectively eliminated.

The negative is projected through a contact screen and a print made on 'reproducible' film. Dimensions, notes, etc., are added to the reproducible film which can be printed by a diazo process—see 4.4.11. These prints are used as working drawings, and distributed to those needing information.

## REVAMP WORK FOR EXISTING PLANTS

A Polaroid (or video) camera can be used to supply views of the plant and unrecorded changes. Filed drawings of a plant do not always include alterations, or deviation from original design.



Photographs of sections of a plant can be combined with drawings to facilitate installation of new equipment, or to make further changes to the existing plant. To do this, photographs are taken of the required views, using a camera fitted with a wide-angle lens (to obtain a wider view).

The negatives obtained are printed onto screened positive films which are attached to the back of a clear plastic drawing sheet. Alterations to the piping system are then drawn on the front face of this sheet, linking the photographs as desired. Reproductions of the composite drawing are made in the usual way by diazo process.

Alternately, positives may be marked directly for minor changes or instructions to the field.

## PHOTOGRAPHIC LAYOUTS

The following technique produces equipment layout 'drawings', and is especially useful for areas where method study or investigational reports are required.

First, equipment outlines are produced to scale on photographic film, either in the regular way or by xerography. Next, a drawing-sized sheet of clear film is laid on a white backing sheet having a correctly-scaled grid marked on it.

The building outline and other features can be put onto the film using the variety of printed transparent tapes and decals available. The pieces of film with equipment outlines may then be positioned with clear tape, and any other parts of the 'drawing' completed. Alterations to the layout may be rapidly made with this technique, which photographs well for reports, and allows prints to be made in the usual ways for marking and comment. The film layout should be covered with an acetate or other protective sheet before insertion in a copying machine.

## REDUCTION BY PHOTOGRAPHY

It is frequently required to include reproductions of diagrams and drawings in reports, etc. Photographic reduction to less than half-size (on lengths) is not recommended because normal-sized printing and details may not be legible. A graphic scale should be included on drawings to be reduced—see chart 5.8.

# DRAFTING: PROCESS AND PIPING DRAWINGS

## including Drawing Symbols, Showing Dimensions, Showing Instrumentation, and Bills of Materiel

### PIPING SYMBOLS

5.1

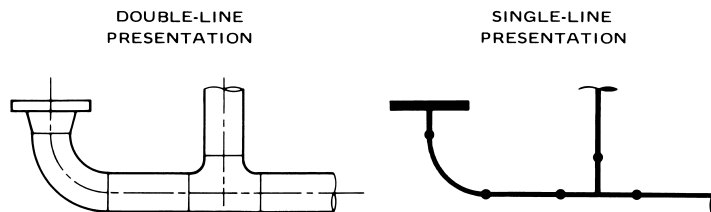
#### SHOWING PIPE & JOINTS

5.1.1

Hand-drawn piping layouts depict pipe by single lines for clarity and economy. Pipe and flanges are sometimes drawn partially 'double line' to display clearances. Computer drawn layouts can show piping in plan, elevational and isometric views in single line, or (without additional effort or expense) in double line. Double line representation is best reserved for three-dimensional views, such as isos.



In double-line drawing, valves are shown by the symbols in chart 5.6 (refer to the panel 'Drafting valves'). Double-line representation is not used for entire piping arrangements, as it is very time-consuming, difficult to read, and not justified technically.



In presenting piping 'single line' on piping drawings, only the centerline of the pipe is drawn, using a solid line (see chart 5.1), and the line size is written. Flanges are shown as thick lines drawn to the scaled outside diameter of the flange. Valves are shown by special symbols drawn to scale. Pumps are shown by drawing the pads on which they rest, and their nozzles: figure 6.21 illustrates this simplified presentation. Equipment and vessels are shown by drawing their nozzles, outlines, and supporting pads.

If there is a piping specification, it is not necessary to indicate welded or screwed joints, except to remove ambiguities—for example, to differentiate between a tee and a stub-in. In most current practice, the symbols for screwed joints and socket welds are normally omitted, although butt welds are often shown.

The ways of showing joints set out in the standard ANSI Y32.2.3 are not typical of current industrial practice. The standard's symbol for a butt-weld as shown in table 5.1 is commonly used to indicate a butt-weld to be made 'in the field' (field weld).

SHOWING NON-FLANGED JOINTS AT ELBOWS

TABLE 5.1

|                                     | BUTT WELD | SOCKET WELD | SCREWED JOINT |
|-------------------------------------|-----------|-------------|---------------|
| SIMPLIFIED PRACTICE *               |           |             |               |
| CONVENTIONAL PRACTICE               |           |             |               |
| ANSI Y32.2.3 (Not current practice) |           |             |               |

\*The joint symbol may be omitted if the type of joint is determined by a piping specification. It is usually preferred to use the dot weld symbol to make the type of construction clear: for example, to distinguish between a tee and a stub-in.

## LINE SYMBOLS WHICH MAY BE USED ON ALL DRAWINGS 5.1.2

Chart 5.1 shows commonly accepted ways of drawing various lines. Many other line symbols have been devised but most of these are not readily recognized, and it is better to state in words the function of special lines, particularly on process flow diagrams and P&ID's. The designer or draftsman should use his current employer's symbols.

| SYMBOLS FOR LINES   |        |
|---|--------|
| LINE SYMBOLS WHICH MAY BE USED ON P&ID's, PROCESS FLOW DIAGRAMS & PIPING DRAWINGS   |        |
| LINE  | SYMBOL |
| <b>PIPING DRAWINGS (PLANS, ELEVATIONS, ISOS AND SPOOL DRAWINGS)</b><br>MATCHLINE<br>OUTLINES OF BUILDINGS, UNITS, ETC.<br>CENTERLINE<br>SINGLE-LINE PIPING<br>PIPING UNDERGROUND, OR OBSCURED BY EQUIPMENT, WALL, ETC.<br>FUTURE PIPING<br>EXISTING PIPING<br>EQUIPMENT OUTLINES, DIMENSION LINES, DOUBLE-LINE PIPING<br>FUTURE EQUIPMENT<br>EXISTING EQUIPMENT |        |
| <b>P&amp;ID's AND PROCESS FLOW DIAGRAMS</b><br>PRIMARY PROCESS, SERVICE OR UTILITY<br>PRIMARY PROCESS, SERVICE OR UTILITY, UNDERGROUND<br>SECONDARY PROCESS, SERVICE OR UTILITY<br>SECONDARY PROCESS, SERVICE OR UTILITY, UNDERGROUND   |        |
| <b>SIGNAL (INSTRUMENT) LINES</b><br>INSTRUMENT AIR (PNEUMATIC SIGNAL)<br>INSTRUMENT LIQUID (HYDRAULIC SIGNAL)<br>ELECTRIC<br>ELECTROMAGNETIC* OR SONIC<br>INSTRUMENT CAPILLARY TUBING<br>* RADIATION: LIGHT, HEAT, RADIO WAVE, ETC.   |        |

## VALVE & EQUIPMENT SYMBOLS FOR P&ID's & PROCESS FLOW DIAGRAMS 5.1.3

Practice in showing equipment is not uniform. Chart 5.2 is based on ANSI Y32.11, and applies to P&ID's and process flow diagrams.

## REPRESENTING PIPING ON PIPING DRAWINGS 5.1.4

Charts 5.3-6 show symbols used in butt-welded, screwed and socket-welded systems. The various aspects of the fitting, valve, etc., are given. These symbols are based on conventional practice rather than the ANSI standard Z32.2.3, titled 'Graphic symbols for pipe fittings, valves and piping'.

## REPRESENTING VALVES ON PIPING DRAWINGS 5.1.5

Chart 5.6 shows ways of denoting valves, including stems, handwheels and other operators. The symbols are based on ANSI Z32.2.3, but more valve types are covered and the presentation is up-dated. Valve handwheels should be drawn to scale with valve stem shown fully extended.

## MISCELLANEOUS SYMBOLS FOR PIPING DRAWINGS 5.1.6

Symbols that are shown in a similar way in all systems are collected in chart 5.7.

## GENERAL ENGINEERING SYMBOLS 5.1.7

Chart 5.8 gives some symbols, signs, etc., which are used generally and are likely to be found or needed on piping drawings.

# PROCESS EQUIPMENT SYMBOLS

CHART 5.2A

## COLUMNS

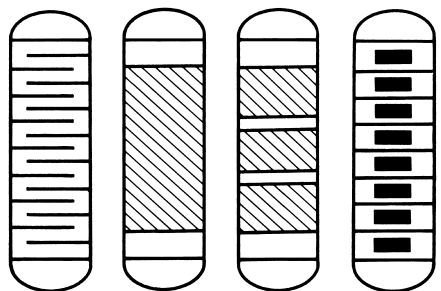
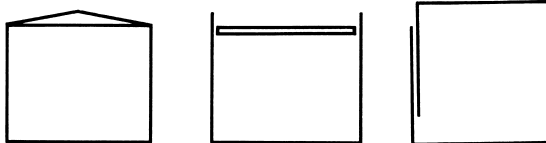


PLATE  
PACKED  
SECTION  
(SECTIONALLY PACKED)  
DISC AND DONUT  
COLUMNS or TOWERS

## TANKS & RESERVOIRS

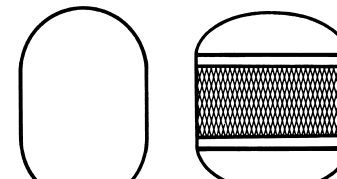


ATMOSPHERIC (CONE ROOF) TANK  
FLOATING-ROOF TANK  
GAS HOLDER



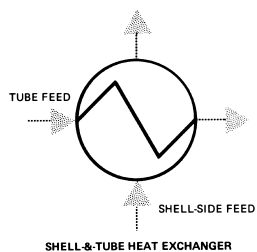
OPEN or VENTED  
PRESSURIZED  
RESERVOIR

## VESSELS

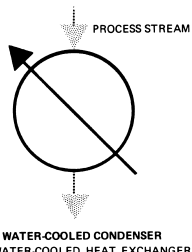


VESSEL  
CATALYTIC REACTOR

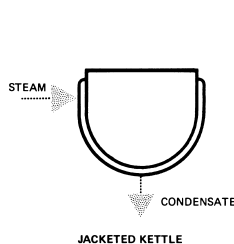
## HEAT-EXCHANGE EQUIPMENT



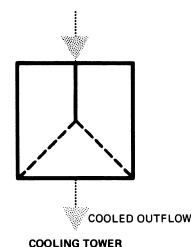
SHELL & TUBE HEAT EXCHANGER



WATER-COOLED CONDENSER  
or WATER-COOLED HEAT EXCHANGER

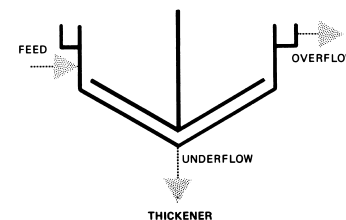


JACKETED KETTLE



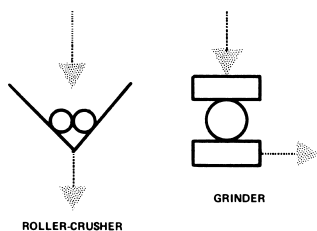
COOLED OUTFLOW  
COOLING TOWER

## THICKENER or CLARIFIER



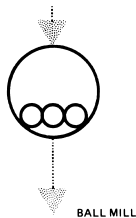
THICKENER

## ATTRITION EQUIPMENT (Mills, grinders, etc.)



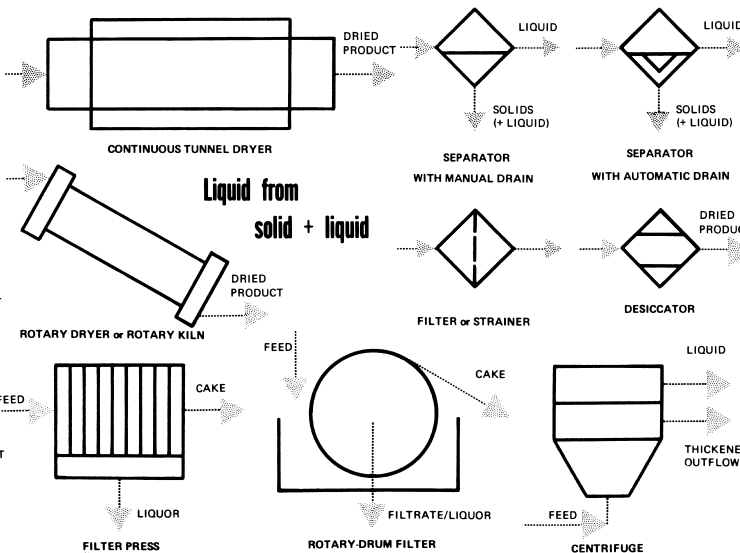
ROLLER-CRUSHER

GRINDER

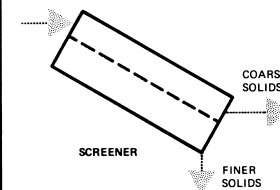


BALL MILL

## SEPARATION EQUIPMENT



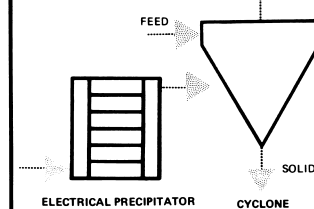
## Solid from solid



SCREENER

COARSE SOLIDS  
FINER SOLIDS

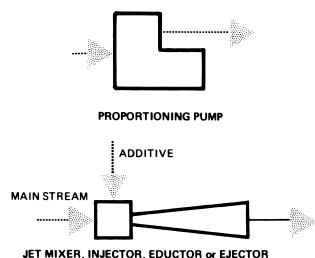
## Solid from solid + gas



ELECTRICAL PRECIPITATOR

CYCLONE

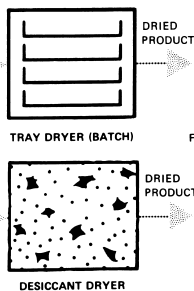
## IN-LINE MIXING EQUIPMENT



PROPORTIONING PUMP

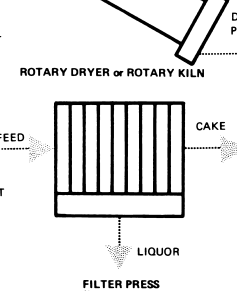
ADDITIVE

MAIN STREAM  
JET MIXER, INJECTOR, EDUCTOR or EJECTOR



TRAY DRYER (BATCH)

DESICCANT DRYER



ROTARY DRYER or ROTARY KILN

FEED

CAKE

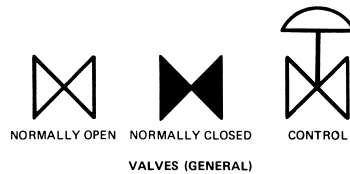
LIQUOR

FILTER PRESS (Plate & Frame)

# PROCESS EQUIPMENT SYMBOLS

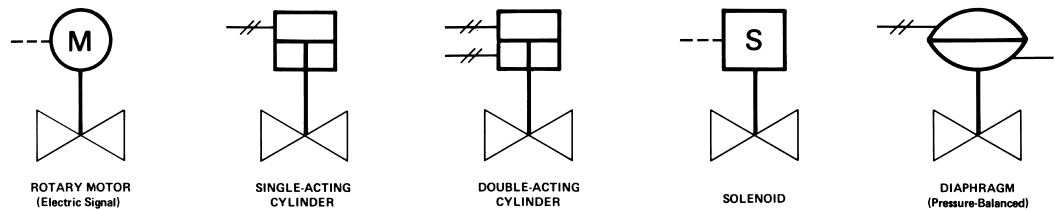
CHART 5.2B

## VALVES

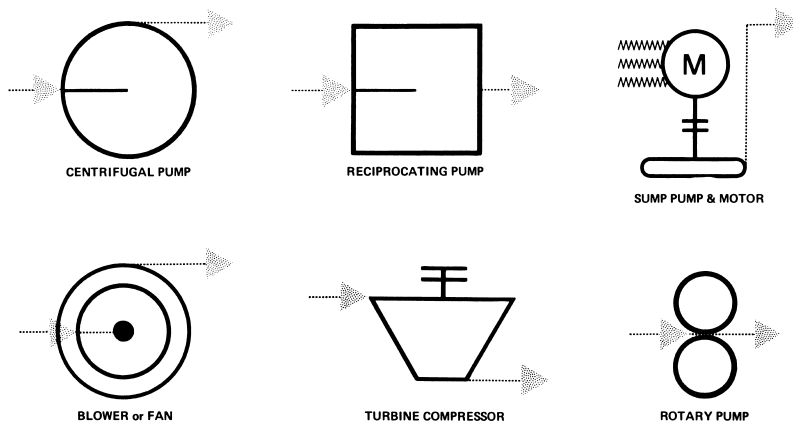


Special types of valve may be indicated by the symbols given in chart 5.6

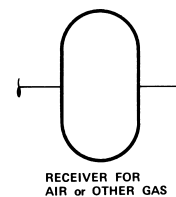
## VALVE OPERATORS (ISA S5.1)



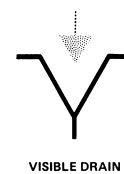
## PUMPS, COMPRESSOR, BLOWER, & FAN



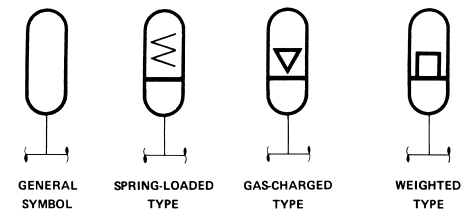
## RECEIVER



## DRAIN

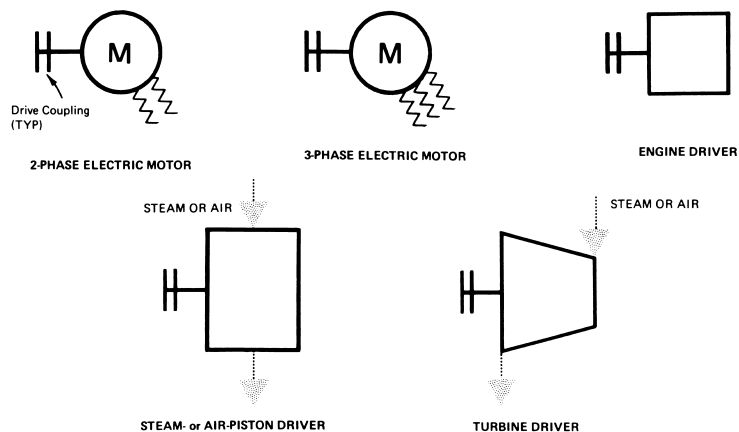


## ACCUMULATORS

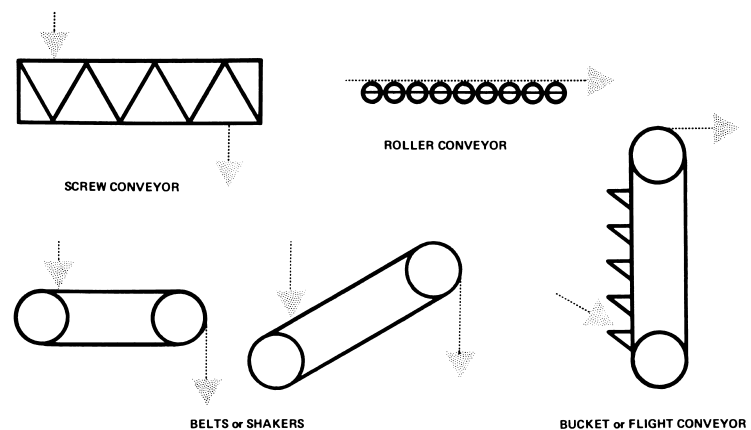


THESE SYMBOLS CAN BE USED FOR HYDRAULIC OR PNEUMATIC ACCUMULATORS, USED TO SMOOTH THE PULSATING OUTFLOW FROM PUMPS AND COMPRESSORS, OR TO ACT AS RESERVOIRS FOR VARIABLE DEMAND.

## DRIVERS



## CONVEYORS



# SYMBOLS FOR BUTT-WELDED SYSTEMS

## CHART 5.3

### NOTE

IN CHARTS 5.3 THRU 5.5, THE SYMBOL IS SHOWN IN HEAVY LINE. LIGHTER LINES SHOW CONNECTED PIPE, AND ARE NOT A PART OF THE SYMBOL.

| NAME OF ITEM             | END VIEW                  | SIDE VIEW | END VIEW            | NAME OF ITEM                                       | END VIEW              | SIDE VIEW | END VIEW | NAME OF ITEM  | END VIEW                      | SIDE VIEW | END VIEW |
|--------------------------|---------------------------|-----------|---------------------|--|-----------------------|-----------|----------|---|-------------------------------|-----------|----------|
| BEND (State Radius)      |                           |           |                     | LAP JOINT FLANGE & STUB                            |                       |           |          | RETURN  |                               |           |          |
| BUTT WELD                |                           |           |                     | LATERAL  |                       |           |          | SOCKLET   | SHOW AS 'WELDOLET'—THIS CHART |           |          |
| BLIND FLANGE             |                           |           |                     | LATROLET   |                       |           |          | SLIP-ON FLANGE  |                               |           |          |
| CAP                      |                           |           |                     | MITER  | SEE END OF THIS CHART |           |          | STUB-IN   |                               |           |          |
| COUPLING, FULL- or HALF- |                           |           |                     | NIPOLET  |                       |           |          | SWAGE, CONCENTRIC<br>ECCENTRIC<br>STATE WHETHER TOP OR BOTTOM IS 'FLAT' | <b>TOP VIEW</b><br>           |           |          |
| CROSS                    |                           |           |                     | PIPE   |                       |           |          | SWEEPOLET   |                               |           |          |
| ELBOW, 90°, LR           |                           |           |                     | REDUCER, CONCENTRIC                                | <b>TOP VIEW</b><br>   |           |          | THREDOLET   | SHOW AS 'WELDOLET'—THIS CHART |           |          |
| ELBOW, 90°, SR           |                           |           |                     | ECCENTRIC<br>STATE WHETHER TOP OR BOTTOM IS 'FLAT' |                       |           |          | TEE   |                               |           |          |
| ELBOW, 45°               |                           |           |                     | REDUCING FLANGE                                    |                       |           |          | WELDING-NECK FLANGE   |                               |           |          |
| ELBOLET                  |                           |           | <b>TOP VIEW</b><br> | REDUCING ELBOW                                     |                       |           |          | WELDOLET  |                               |           |          |
| EXPANDER FLANGE          |                           |           |                     | REINFORCEMENTS<br>SADDLE                           |                       |           |          | 2-PIECE MITER   |                               |           |          |
| FIELD WELD               |                           |           |                     | WRAPAROUND SADDLE                                  |                       |           |          | 3-PIECE MITER   |                               |           |          |
| FULL-COUPLING            | SEE 'COUPLING' THIS CHART |           |                     |  |                       |           |          |   |                               |           |          |
| HALF-COUPLING            | SEE 'COUPLING' THIS CHART |           |                     |  |                       |           |          |   |                               |           |          |
| HOSE                     |                           |           |                     |  |                       |           |          |   |                               |           |          |
| HOSE COUPLING            |                           |           |                     |  |                       |           |          |   |                               |           |          |

## SYMBOLS FOR SCREWED SYSTEMS

CHART 5.4

| NAME OF ITEM   | END VIEW   | SIDE VIEW | END VIEW |
|--|--|-----------|----------|
| CAP  |  |           |          |
| COUPLING,<br>FULL- & HALF-   | SHOW FOR BRANCH CONNECTIONS ONLY—<br>SEE 'COUPLING' IN CHART 5.3 |           |          |
| CROSS  |  |           |          |
| ELBOW, 90°   |  |           |          |
| ELBOW, 45°   |  |           |          |
| FLANGE   |  |           |          |
| HOSE   |  |           |          |
| HOSE CONNECTION  |  |           |          |
| PIPE   |  |           |          |
| PLUG   |  |           |          |
| REDUCER  |  |           |          |
| RETURN<br><i>Only malleable-iron and cast-iron returns are available. For forged-steel systems, combine forged-steel elbows.</i> |  |           |          |
| SEAL WELD  | SHOW BY NOTING 'SEAL WELD'                                       |           |          |
| SWAGE,<br>CONCENTRIC   | <b>TOP VIEW</b><br>  |           |          |
| ECCENTRIC<br>STATE WHETHER TOP<br>OR BOTTOM IS 'FLAT'  |  |           |          |
| TEE,<br>STRAIGHT or REDUCING   |  |           |          |
| THREDOLET  | SHOW AS 'WELDOLET'—CHART 5.3                                     |           |          |
| UNION  |  |           |          |

## SYMBOLS FOR SOCKET-WELDED SYSTEMS

CHART 5.5

| NAME OF ITEM  | END VIEW   | SIDE VIEW | END VIEW |
|---|--|-----------|----------|
| CAP   |  |           |          |
| COUPLING,<br>FULL- & HALF-                            | SHOW FOR BRANCH CONNECTIONS ONLY—<br>SEE 'COUPLING' IN CHART 5.3   |           |          |
| CROSS   |  |           |          |
| ELBOLET   | SEE 'ELBOLET'—CHART 5.3  |           |          |
| ELBOW, 90°  |  |           |          |
| ELBOW, 45°  |  |           |          |
| FLANGE  |  |           |          |
| HOSE  |  |           |          |
| PIPE  |  |           |          |
| REDUCER,  |  |           |          |
| RETURN  | NO SOCKET-WELDING FORGED-STEEL FITTING IS AVAILABLE. IF A 180-DEGREE RETURN IS REQUIRED, IT MAY BE MADE USING A BUTT-WELDING RETURN, OR TWO SOCKET-WELDING ELBOWS WITH NIPPLE BETWEEN. |           |          |
| SOCKOLET  | SHOW AS 'WELDOLET'—CHART 5.3   |           |          |
| SWAGE,<br>CONCENTRIC                                  | <b>TOP VIEW</b><br>  |           |          |
| ECCENTRIC<br>STATE WHETHER TOP<br>OR BOTTOM IS 'FLAT' |  |           |          |
| TEE,<br>STRAIGHT or REDUCING                          |  |           |          |
| UNION   |  |           |          |

## DRAFTING VALVES

CHART 5.6 GIVES THE BASIC SYMBOLS FOR VALVES. THESE BASIC SYMBOLS ARE USED OR ADAPTED AS FOLLOWS:

### P & I D's

USE THE RELEVANT VALVE SYMBOL TO SHOW THE TYPE OF VALVE. DRAW MOST SYMBOLS 1/4-in. LONG. MANUAL OPERATORS ARE NOT SHOWN.

### PIPING DRAWINGS

OPERATOR IS SHOWN IF IMPORTANT

(1) SCREWED VALVES

USE THE BASIC VALVE SYMBOL. DRAW THE LENGTH OF THE VALVE TO SCALE.

(2) SOCKET-ENDED VALVES

IF THE PROJECT HAS A PIPING SPECIFICATION, USE THE BASIC VALVE SYMBOL. IF NOT, SHOW SOCKET ENDS TO THE VALVES:

| VALVE WITH:    | Sockets both ends | Socket one end, other end plain |
|----------------|-------------------|---------------------------------|
| SYMBOL EXAMPLE |                   |                                 |

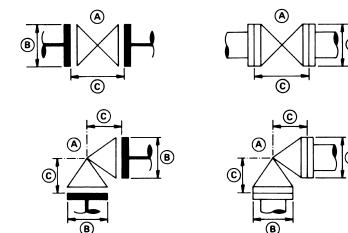
DRAW THE LENGTH OF THE BASIC VALVE SYMBOL TO SCALE OVER SOCKET ENDS.

(3) FLANGED VALVES

USE THE BASIC VALVE SYMBOL, WITH OPERATOR, AND SHOW MATING FLANGES AS DETAILED BELOW:

| SINGLE-LINE | DOUBLE-LINE |
|-------------|-------------|
|-------------|-------------|

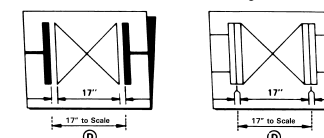
### 1. Drawing the symbol



- (A) Show the basic valve symbol between flanges.
- (B) Draw flange OD to scale.
- (C) Draw these lengths scaled to the flange-face-to-flange-face or center-to-flange-face dimensions for the valve.

### 2. Dimensioning nonstandard valves

Refer to 5.3.3, under 'Dimensioning to valves'



- (D) Draw this length to scale (overall length of valve without gaskets) but place arrowheads on the drawing as shown. This convention ensures that:
  - (1) The line will be made to the correct length.
  - (2) The fabricator will be reminded to allow for gaskets.

# SYMBOLS FOR VALVES AND VALVE OPERATORS

## CHART 5.6

| TYPE OF VALVE  | SIDE VIEW        | TOP VIEW | TYPE OF VALVE  | SIDE VIEW                  | TOP VIEW | TYPE OF VALVE                   | SIDE VIEW | TOP VIEW |
|--|------------------|----------|--|----------------------------|----------|---------------------------------|-----------|----------|
| ANGLE GLOBE  |                  |          | (a) LINE-BLIND VALVE<br>(Using spectacle plate)<br>(b) LINE BLIND<br>(Shown between flanges) | (a)                        | (b)      | VACUUM BREAKER<br>(or Breather) |           |          |
| BALL, ROTARY   |                  |          | NEEDLE   |                            |          | WYE-PATTERN GLOBE               |           |          |
| BUTTERFLY  |                  |          | PINCH  | USE 'SQUEEZE VALVE' SYMBOL |          | 3-WAY                           |           |          |
| CHECK (SWING)<br><i>Position of dot here shows<br/>flow from left to right</i> |                  |          | PLUG   |                            |          | 4-WAY                           |           |          |
| COCK   | SEE 'PLUG VALVE' |          | 'QUICK OPENING'  |                            |          | OPERATOR                        | SIDE VIEW | END VIEW |
| CONTROL  |                  |          | RELIEF   |                            |          | SPUR GEAR                       |           |          |
| DIAPHRAGM  |                  |          | SAFETY   |                            |          | BEVEL GEAR                      |           |          |
| FLUSH-BOTTOM<br>TANK VALVE   |                  |          | SAFETY-RELIEF  |                            |          | CHAIN WHEEL                     |           |          |
| GATE   |                  |          | STOP CHECK   |                            |          | CHAIN WRENCH                    |           |          |
| GLOBE  |                  |          | SQUEEZE  |                            |          |                                 |           |          |
|  |                  |          | TRAP   |                            |          |                                 |           |          |

THIS CHART GIVES THE BASIC VALVE SYMBOL WHICH IS USED ON P&ID's AND FLOW DIAGRAMS.  
ADAPTATION OF THE SYMBOLS TO PIPING DRAWINGS IS EXPLAINED ON THE FACING PAGE <

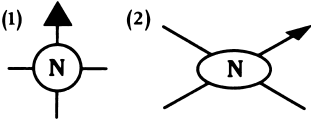



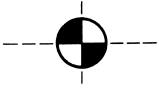
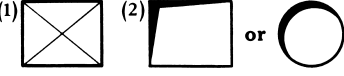
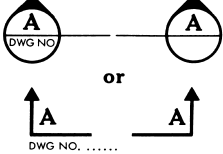

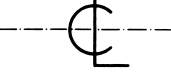
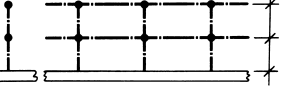
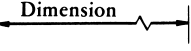
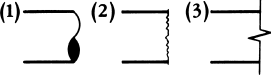

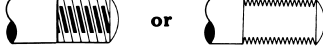
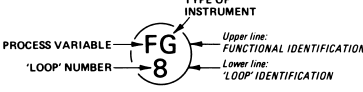
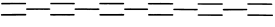
# MISCELLANEOUS SYMBOLS FOR PIPING DRAWINGS

## CHART 5.7

| NAME OF ITEM                      | SYMBOL | NAME OF ITEM   | SYMBOL                             | NAME OF ITEM    | SYMBOL  |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
|-----------------------------------|--------|--|------------------------------------|-----------------|---|---------|--------|--------|--|-------|--|------|--|--------|--|---------------|--|---------------|--|----------------|--|
| BLEED RING                        |        | JACKETED PIPE WITH INSULATION                          |                                    | TRAP            |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| CONTROL STATION<br>(in Plan View) |        | ORIFICE FLANGE ASSEMBLY                                |                                    | VENT (for line) |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| DRAIN or HUB (in floor)           |        | PERSONNEL PROTECTION<br>(Protective use of insulation) |                                    | VENT FOR TANK   |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| DRAIN (for line)                  |        | QUICK CONNECTORS                                       | (1) Without Checks<br>Disconnected |                 | <div>PIPE SUPPORT SYMBOLS</div> <table><tr><th>SUPPORT</th><th>SYMBOL</th></tr><tr><td>ANCHOR</td><td></td></tr><tr><td>GUIDE</td><td></td></tr><tr><td>SHOE</td><td></td></tr><tr><td>HANGER</td><td></td></tr><tr><td>SPRING HANGER</td><td></td></tr><tr><td>FLOOR SUPPORT</td><td></td></tr><tr><td>SPRING SUPPORT</td><td></td></tr></table> | SUPPORT | SYMBOL | ANCHOR |  | GUIDE |  | SHOE |  | HANGER |  | SPRING HANGER |  | FLOOR SUPPORT |  | SPRING SUPPORT |  |
| SUPPORT                           | SYMBOL |  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| ANCHOR                            |        |  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| GUIDE                             |        |  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| SHOE                              |        |  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| HANGER                            |        |  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| SPRING HANGER                     |        |  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| FLOOR SUPPORT                     |        |  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| SPRING SUPPORT                    |        |  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| EDUCTOR                           |        | Connected  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| EJECTOR                           |        | (2) With Checks<br>Disconnected                        |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| ELECTRIC TRACING                  |        | Connected  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| EXHAUST HEAD<br>(for steam)       |        | REMOVABLE SPOOL  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| EXPANSION JOINT                   |        | RUPTURE DISC   |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| FLAME ARRESTOR                    |        | SCREEN<br>Conical,<br>Mounted between Flanges          |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| FLEXIBLE COUPLING                 |        | SCREEN<br>Flat,<br>Mounted between Flanges             |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| HOSE                              |        | STEAM TRACING  |                                    |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
| INSULATION                        |        | STRAINER, WYE-TYPE                                     | (Flow from L. to R.)               |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
|                                   |        |  | BUTT-WELDING                       |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
|                                   |        |  | SOCKET-WELDING                     |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
|                                   |        |  | FLANGED                            |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |
|                                   |        |  | SCREWED                            |                 |   |         |        |        |  |       |  |      |  |        |  |               |  |               |  |                |  |




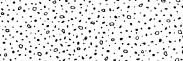
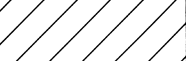


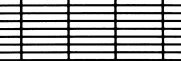
# GENERAL SYMBOLS FOR ENGINEERING DRAWINGS

CHART 5.8

| SYMBOL  | DESCRIPTION  | SYMBOL  | DESCRIPTION  |
|---|--|---|--|
|    | <p>NORTH ARROWS.</p> <p>(1) FOR PLANS AND ELEVATIONS</p> <p>(2) FOR ISOMETRIC DRAWINGS</p>   |    | <p>'CONSTRUCTION HOLD' MARKING. IF SUFFICIENT INFORMATION IS NOT AVAILABLE TO FINALIZE PART OF THE DESIGN, THE 'HOLD' MARKING IS USED TO INSTRUCT THE CONTRACTOR TO AWAIT A LATER REVISION OF THE DRAWING BEFORE STARTING THE WORK IN QUESTION</p> |
|    | <p>GRAPHIC SCALE REQUIRED ON DRAWINGS LIKELY TO BE CHANGED IN SIZE PHOTOGRAPHICALLY FOR REPORTS, etc.</p>  |    | <p>REVISION TRIANGLE. THE LATEST REVISION NUMBER OF THE DRAWING IS SHOWN WITHIN THE TRIANGLE WHICH IS ENCIRCLED ON THE REAR OF THE SHEET. ALL REVISION TRIANGLES REMAIN ON THE DRAWING, BUT ENCIRCLING OF THE PREVIOUS TRIANGLE IS ERASED</p>      |
|    | <p>SYMBOL LOCATING AXES OF REFERENCE: INTERSECTION OF ORDINATES (COORDINATE POINT)</p>   |    | <p>OPENINGS.</p> <p>(1) OPENING WHICH MAY BE COVERED. (ARCH. AND H&amp;V DRAWINGS)</p> <p>(2) HOLE. (ARCH.)</p>  |
|    | <p>TYPICAL SECTION INDICATORS. LETTERS 'I' AND 'O' SHOULD NOT BE USED TO AVOID CONFUSION WITH NUMERALS '1' AND '0'. IF MORE THAN 24 SECTIONS ARE NEEDED, USE COMBINATIONS OF LETTERS AND NUMERALS. SHOW NUMBER OF THE DRAWING ON WHICH SECTION WILL APPEAR</p> |    | <p>STRUCTURAL STEEL SECTIONS:</p> <p>(1) ANGLE. (2) CHANNEL. (3) I-BEAM</p>  |
|    | <p>CENTERLINE SYMBOL</p>   |    | <p>ELEVATION SYMBOLS FOR RAILING</p>   |
|  | <p>DIMENSION LINE SYMBOL USED TO SHOW A DIMENSION NOT TO SCALE</p>   |  | <p>DISCONTINUED VIEWS:</p> <p>(1) PIPE, ROUND SHAFT, etc.</p> <p>(2) SLAB, SQUARE BAR, etc.</p> <p>(3) VESSEL, EQUIPMENT, etc.</p> <p>(Also used to terminate drawing)</p>   |
|  | <p>'FITTING MAKEUP' SYMBOL (NOT PREFERRED – SEE 5.3.3, UNDER 'FITTING MAKEUP')</p>   |  | <p>SCREWTHREAD SYMBOLS</p>   |
|  | <p>INSTRUMENT BALLOON, USUALLY DRAWN 7/16-INCH DIAMETER ON P&amp;ID's AND PIPING DRAWINGS (TO 3/8 IN. PER FT SCALE)</p>  |  | <p>CHAIN SYMBOL</p>  |

## SHADINGS

THESE SHADINGS ARE USED FOR SHOWING MATERIALS AND SECTIONS OF SOLIDS

| GRADE or EARTH  | SOLID MATERIAL (and pipe cross section)   | STEEL   | CONCRETE   | BRICK & STONE MASONRY   | WOOD  | CHECKER PLATE (Use 30° lines)   | GRATING   |
|---|---|---|--|---|---|---|---|
|  |  |  |  |  |  |  |  |

# WELDING SYMBOLS (American Welding Society)



## CHART 5.9

| Basic Welding Symbols and Their Location Significance |          |              |                    |          |          |                 |             |                        |             |
|---|----------|--------------|--------------------|----------|----------|-----------------|-------------|------------------------|-------------|
| Location Significance                                 | Fillet   | Plug or Slot | Spot or Projection | Stud     | Seam     | Back or Backing | Surfacing   | Flange Corner          | Flange Edge |
| Arrow Side  |          |              |                    |          |          |                 |             |                        |             |
| Other Side  |          |              |                    | Not used |          |                 | Not used    |                        |             |
| Both Sides  |          | Not used     | Not used           | Not used |          |                 | Not used    | Not used               | Not used    |
| No Arrow Side or Other Side Significance              | Not used | Not used     |                    | Not used |          |                 | Not used    | Not used               | Not used    |
| Location Significance                                 | Square   | V            | Bevel              | Groove   | J        | Flare-V         | Flare-Bevel | Scarf for Brazed Joint |             |
| Arrow Side  |          |              |                    |          |          |                 |             |                        |             |
| Other Side  |          |              |                    |          |          |                 |             |                        |             |
| Both Sides  |          |              |                    |          |          |                 |             |                        |             |
| No Arrow Side or Other Side Significance              |          | Not used     | Not used           | Not used | Not used | Not used        | Not used    | Not used               |             |

| Supplementary Symbols |            |           |                   |                |       |         |
|-----------------------|------------|-----------|-------------------|----------------|-------|---------|
| Weld-All Around       | Field Weld | Melt-Thru | Consumable Insert | Backing Spacer | Flush | Contour |
|                       |            |           |                   |                |       |         |
|                       |            |           |                   |                |       |         |

| Basic Joints Identification of Arrow Side and Other Side of Joint |              |  |  |  |  |  |
|---|--------------|--|--|--|--|--|
| Butt Joint  | Corner Joint |  |  |  |  |  |
|   |              |  |  |  |  |  |
|   |              |  |  |  |  |  |

| T-Joint | Lap Joint | Edge Joint | Process Abbreviations   |
|---------|-----------|------------|---|
|         |           |            | Where process abbreviations are to be included in the tail of the welding symbol, reference is made to Table 1, Designation of Welding and Allied Processes by Letters, of AWS A2.4-86. |
|         |           |            | AMERICAN WELDING SOCIETY, INC.<br>550 N.W. LeJeune Road<br>P.O. Box 351040, Miami, Florida 33135  |

Reproduced from AWS A2.4-86: Symbols for Welding, Brazing and Nondestructive Examination, by permission of the American Welding Society. A complete copy of A2.4-86 may be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami Florida 33126. Telephone (305) 443-9353.

## SYMBOLS FOR WELDING DETAILS

### 5.1.8

Standard welding symbols are published by the American Welding Society. These symbols should be used as necessary on details of attachments, vessels, piping supports, etc. The practice of writing on drawings instructions such as 'TO BE WELDED THROUGHOUT', or 'TO BE COMPLETELY WELDED' transfers the design responsibility for all attachments and connections from the designer to the welder, which the Society considers to be a dangerous and uneconomic practice.

The 'welding symbol' devised by the American Welding Society has eight elements. Not all of these elements are necessarily needed by piping designers. The assembled welding symbol which gives the welder all the necessary instruction, and locations of its elements, is shown in chart 5.9. The elements are:

- REFERENCE LINE
- ARROW
- BASIC WELD SYMBOLS
- DIMENSIONS & OTHER DATA
- SUPPLEMENTARY SYMBOLS
- FINISH SYMBOLS
- TAIL
- SPECIFICATIONS, PROCESS or OTHER REFERENCE

The following is a quick guide to the scheme. Full details will be found in the current revision of 'Standard Welding Symbols' available from the American Welding Society.

### ASSEMBLING THE WELDING SYMBOL

Reference line and arrow: The symbol begins with a reference line and arrow pointing to the joint where the weld is to be made. The reference line has two 'sides': 'other side' (above the line) and 'arrow side' (below the line)—refer to the following examples and to chart 5.9.

#### BASIC WELDING ARROW

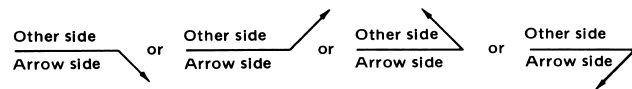


FIGURE 5.1

#### BASIC WELDING SYMBOLS

##### (a) The weld symbol

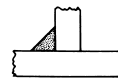
| FILLET      | BACK, or<br>BACKING | PLUG or SLOT | SPOT, or<br>PROJECTION | SEAM | EDGE<br>FLANGE | CORNER<br>FLANGE |
|-------------|---------------------|--------------|------------------------|------|----------------|------------------|
| ARROW →<br> |                     |              |                        |      |                |                  |

##### (b) The groove symbol

| SQUARE      | 'V' | BEVEL | 'U' | 'J' | FLARE-'V' | FLARE-BEVEL |
|-------------|-----|-------|-----|-----|-----------|-------------|
| ARROW →<br> |     |       |     |     |           |             |

### EXAMPLE USE OF THE FILLET WELD SYMBOL

If a continuous fillet weld is needed, like this:



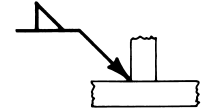
the fillet weld symbol is placed on the 'arrow side' of the reference line, thus:



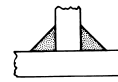
If the weld is required on the far side from the arrow, thus:



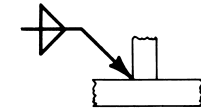
the weld symbol is shown on the 'other side' of the reference line:



If a continuous fillet weld is needed on both sides of the joint,



the fillet weld symbol is placed on both sides of the reference line:

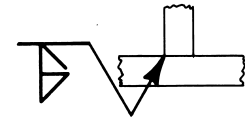


### EXAMPLE USE OF THE BEVEL GROOVE SYMBOL

If a bevel groove is required, like this:



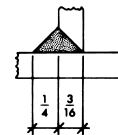
The 'groove' symbol for a bevel is shown, with the fillet weld symbol, and a break is made in the arrow toward the member to be beveled, thus:



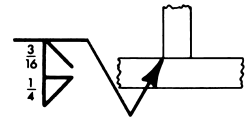
Only the bevel and 'J' groove symbols require a break in the arrow—see chart 5.9.

### DIMENSIONING THE WELD CROSS SECTION

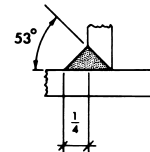
Suppose the weld is required to be 1/4 inch in size, and the bevel is to be 3/16 inch deep:



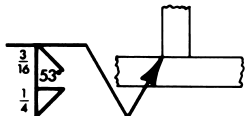
These dimensions are shown to the left of the weld symbol:



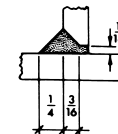
Alternatively, the bevel can be expressed in degrees of arc:



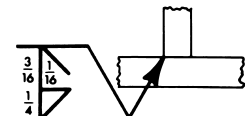
and be indicated thus on the symbol:



If a root gap is required, thus:

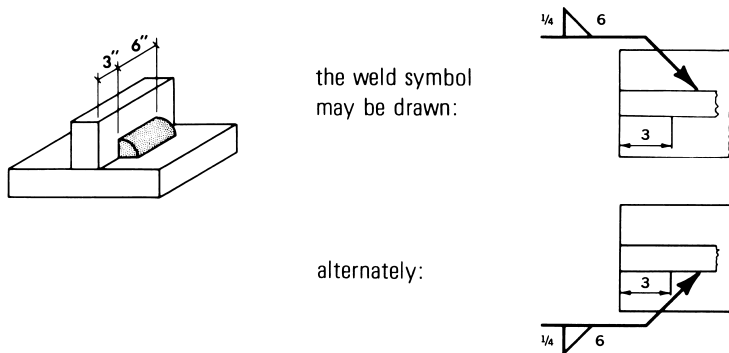


the symbol is:

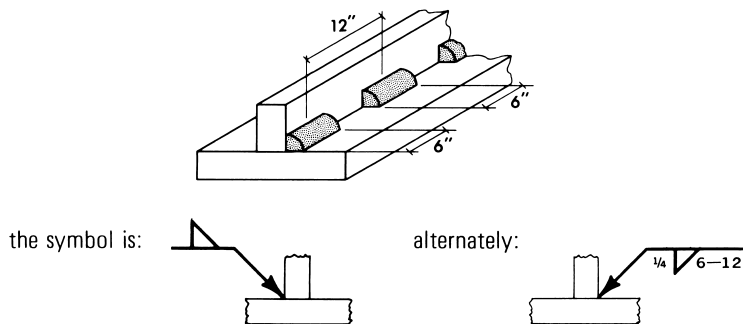


## DIMENSIONING THE LENGTH OF THE WELD

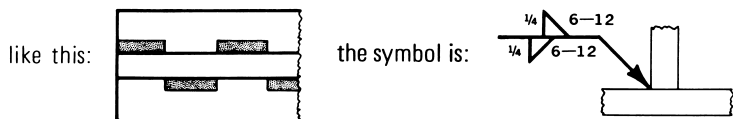
Going back to the fillet weld joint without a bevel, if the weld needs to be 1/4-inch in size and 6 inches long, like this:



If a series of 6-inch long welds is required with 6-inch gaps between them (that is, the pitch of the welds is 12 inches), thus:



If these welds are required staggered on both sides—

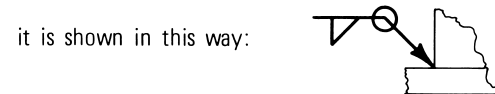
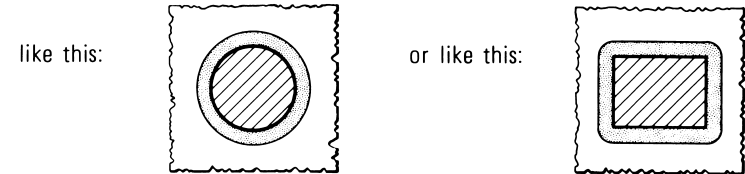


## SUPPLEMENTARY SYMBOLS

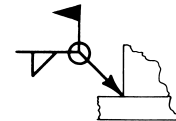
These symbols give instructions for making the weld and define the required contour:

| WELD ALL AROUND | FIELD WELD | MELT-THRU | CONTOUR |        |         |
|-----------------|------------|-----------|---------|--------|---------|
|                 |            |           | FLUSH   | CONVEX | CONCAVE |
|                 |            |           |         |        |         |

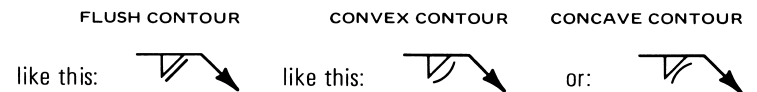
Going back to the example of a simple fillet weld, if the weld is required all around a member,



If this same 'all around' weld has to be made in the field, it is shown thus:



The contour of the weld is shown by a contour symbol on the weld symbol:



The method of finishing the weld contour is indicated by adding a finish notation letter, thus,



where M = machining, G = grinding, and C = chipping.

## FULL WELDING SYMBOL

Occasionally it is necessary to give other instructions in the welding symbol. The symbol can be elaborated for this as shown in 'Location of elements of a welding symbol' in chart 5.9.

Chart 5.9, reproduced by permission of the American Welding Society, summarizes and amplifies the explanations of this section.

All information for constructing piping systems is contained in drawings, apart from the specifications, and the possible use of a model and photographs.

THE MAIN PURPOSE OF A DRAWING IS TO COMMUNICATE INFORMATION IN A SIMPLE AND EXPLICIT WAY.

### PROCESS & PIPING DRAWINGS GROW FROM THE SCHEMATIC DIAGRAM

#### 5.2.1

To design process piping, three types of drawing are developed in sequence from the schematic diagram (or 'schematic') prepared by the process engineer.

These three types of drawing are, in order of development:—

- (1) **FLOW DIAGRAM (PROCESS, or SERVICE)**
- (2) **PIPING AND INSTRUMENTATION DIAGRAM, or 'P&ID'**
- (3) **PIPING DRAWING**

### EXAMPLE DIAGRAMS

Figure 5.2 shows a simple example of a 'schematic'. A solvent recovery system is used as an example. Based on the schematic diagram of figure 5.2, a developed process flow diagram is shown in figure 5.3. From this flow diagram, the P&ID (figure 5.4) is evolved.

As far as practicable, the flow of material(s) should be from left to right. Incoming flows should be arrowed and described down the left-hand edge of the drawing, and exiting flows arrowed and described at the right of the drawing, without intruding into the space over the title block.

Information normally included on the process drawings is detailed in sections 5.2.2 thru 5.2.4. Flow diagrams and P&ID's each have their own functions and should show only that information relevant to their functions, as set out in 5.2.3 and 5.2.4. Extraneous information such as piping, structural and mechanical notes should not be included, unless essential to the process.

### SECURITY

A real or supposed need for industrial or national security may restrict information appearing on drawings. Instead of naming chemicals, indeterminate or traditional terms such as 'sweet water', 'brine', 'leach acid', 'chemical B', may be used. Data important to the reactions such as temperatures, pressures and flow rates may be withheld. Sometimes certain key drawings are locked away when not in use.

Commonly referred to as a 'schematic', this diagram shows paths of flow by single lines, and operations or process equipment are represented by simple figures such as rectangles and circles. Notes on the process will often be included.

The diagram is not to scale, but relationships between equipment and piping with regard to the process are shown. The desired spatial arrangement of equipment and piping may be broadly indicated. Usually, the schematic is not used after the initial planning stage, but serves to develop the process flow diagram which then becomes the primary reference.

### FLOW DIAGRAM

#### 5.2.3

This is an unscaled drawing describing the process. It is also referred to as a 'flow sheet'.

It should state the materials to be conveyed by the piping, conveyors, etc., and specify their rates of flow and other information such as temperature and pressure, where of interest. This information may be 'flagged' (on lines) within the diagram or be tabulated on a separate panel—such a panel is shown at the bottom left of figure 5.3.

### LAYOUT OF THE FLOW DIAGRAM

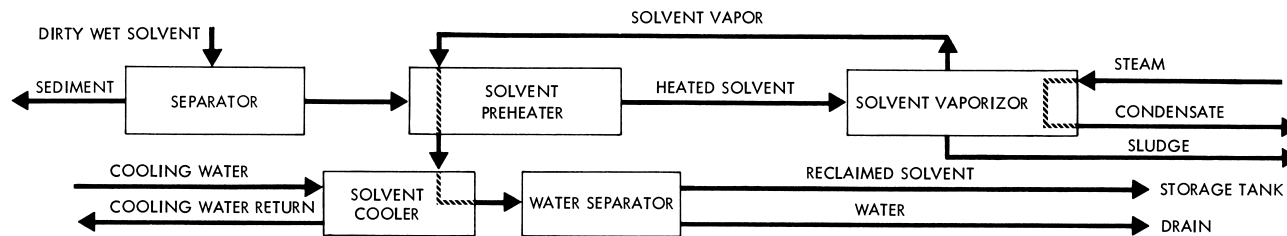
Whether a flow diagram is to be in elevation or plan view should depend on how the P&ID is to be presented. To easily relate the two drawings, both should be presented in the same view. Elevations are suitable for simple systems arranged vertically. Installations covering large horizontal areas are best shown in plan view.

Normally, a separate flow diagram is prepared for each plant process. If a single sheet would be too crowded, two or more sheets may be used. For simple processes, more than one may be shown on a sheet. Process lines should have the rate and direction of flow, and other required data, noted. Main process flows should preferably be shown going from the left of the sheet to the right. Line sizes are normally not shown on a flow diagram. Critical internal parts of vessels and other items essential to the process should be indicated.

All factors considered, it is advisable to write equipment titles *either near the top or near the bottom of the sheet*, either directly above or below the equipment symbol. Sometimes it may be directed that all pumps be drawn at a common level near the bottom of the sheet, although this practice may lead to a complex-looking drawing. Particularly with flow diagrams, simplicity in presentation is of prime importance.

# SCHEMATIC DIAGRAM

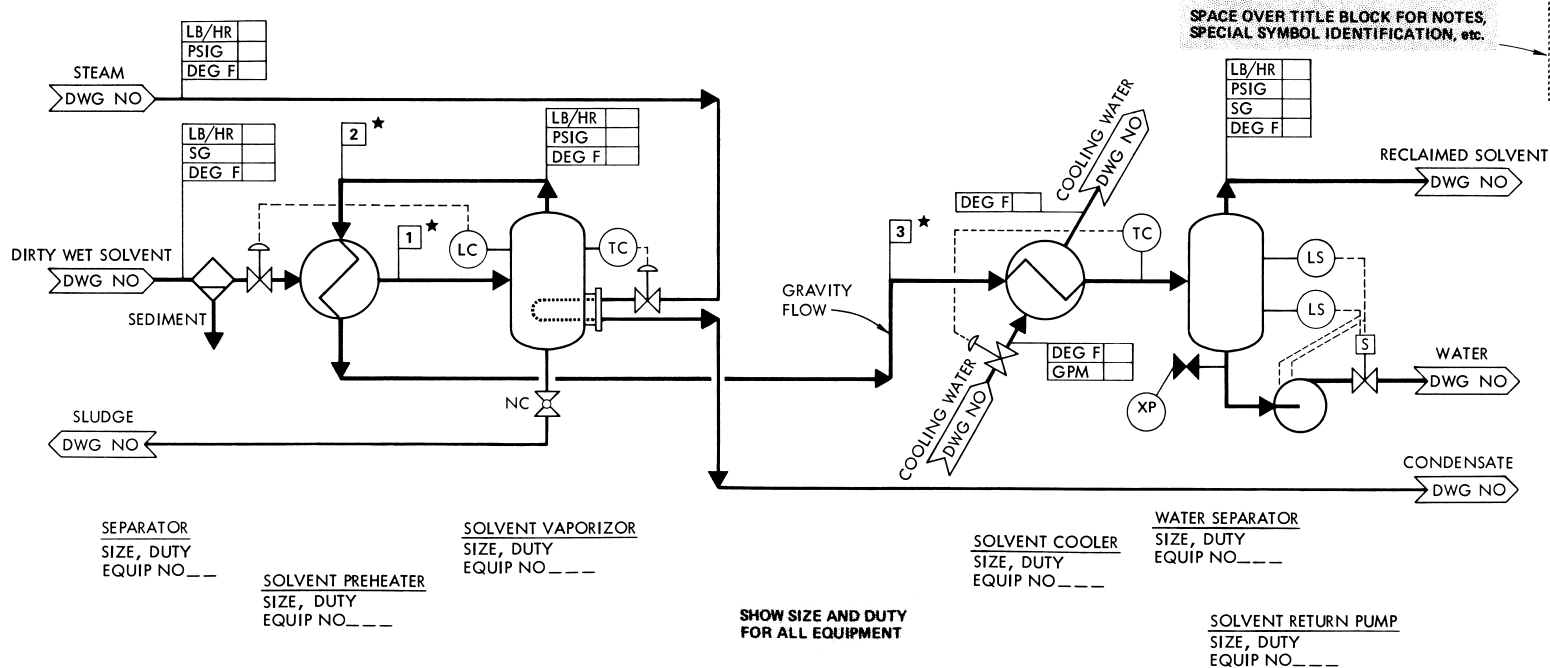
FIGURE 5.2



# PROCESS FLOW DIAGRAM

THIS DIAGRAM SHOWS THE MANNER OF PRESENTATION ONLY—A WORKING DRAWING WOULD BE DEVELOPED TO INCLUDE MORE INFORMATION

FIGURE 5.3

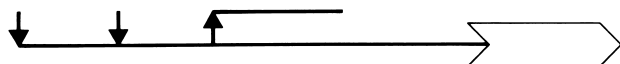


## FLOW LINES

Directions of flow within the diagram are shown by solid arrowheads. The use of arrowheads at all junctions and corners aids the rapid reading of the diagram. The number of crossings can be minimized by good arrangement. Suitable line thicknesses are shown at full size in chart 5.1. For photographic reduction, lines should be spaced not closer than 3/8 inch.

Process and service streams entering or leaving the flow diagram are shown by large hollow arrowheads, with the conveyed fluid written over and the continuation sheet number within the arrowhead, as in figure 5.3.

## ARROWS ON FLOW DIAGRAMS



## SHOWING VALVES ON THE FLOW DIAGRAM

Instrument-controlled and manual valves which are necessary to the process are shown. The following valves are shown if required by a governing code or regulation, or if they are essential to the process: isolating, bypassing, venting, draining, sampling, and valves used for purging, steamout, etc., for relieving excess pressure of gases or liquids (including rupture discs), breather valves and vacuum breakers.

## SHOW ONLY SPECIAL FITTINGS

Piping fittings, strainers, and flame arrestors should not be shown unless of special importance to the process.

## ESSENTIAL INSTRUMENTATION

Only instrumentation essential to process control should be shown. Simplified representation is suitable. For example, only instruments such as controllers and indicators need be shown: items not essential to the drawing (transmitters, for example) may be omitted.

## EQUIPMENT DATA

Capacities of equipment should be shown. Equipment should be drawn schematically, using equipment symbols, and where feasible should be drawn in proportion to the actual sizes of the items. Equipment symbols should neither dominate the drawing, nor be too small for clear understanding.

## STANDBY & PARALLELED EQUIPMENT

Standby equipment is not normally drawn. If identical units of equipment are provided for paralleled operation (that is, all units on stream), only one unit need normally be drawn. Paralleled or standby units should be indicated by noting the equipment number and the service function ('STANDBY' or 'PARALLEL OP').

It is advisable to draw equipment that is operated cyclically. For example, with filter presses operated in parallel, one may be shown on-stream, and the second press for alternate operation.

## PROCESS DATA FOR EQUIPMENT

The basic process information required for designing and operating major items of equipment should be shown. This information is best placed immediately below the title of the equipment.

## IDENTIFYING EQUIPMENT

Different types of equipment may be referred to by a classification letter (or letters). There is no generally accepted coding — each company has its own scheme if any standardization is made at all. Equipment classed under a certain letter is numbered in sequence from '1' upward. If a new installation is made in an existing plant, the method of numbering may follow previous practice for the plant.

Also, it is useful to divide the plant and open part of the site as necessary into areas, giving each a code number. An area number can be made the first part of an equipment number. For example, if a heat exchanger is the 53rd item of equipment listed under the classification letter 'E', located in area '1', (see 'Key plan' in 5.2.7) the exchanger's equipment number can be 1-E-53.

Each item of equipment should bear the same number on all drawings, diagrams and listings. Standby or identical equipment, if in the same service, may be identified by adding the letters, A, B, C, and so on, to the same equipment identification letter and number. For example, a heat exchanger and its standby may be designated 1-E-53A, and 1-E-53B.

## SERVICES ON PROCESS FLOW DIAGRAMS

Systems for providing services should not be shown. However, the type of service, flow rates, temperatures and pressures should be noted at consumption rates corresponding to the material balance—usually shown by a 'flag' to the line—see figure 5.3.

## DISPOSAL OF WASTES

The routes of disposal for all waste streams should be indicated. For example, arrows or drain symbols may be labelled with destination, such as 'chemical sewer' or 'drips recovery system'. In some instances the disposal or waste-treatment system may be detailed on one or more separate sheets. See 6.13 where 'effluent' is discussed.

## MATERIAL BALANCE

The process material balance can be tabulated on separate 8½ x 11-inch sheets, or along the bottom of the process flow diagram.

This drawing is commonly referred to as the 'P&ID'. Its object is to indicate all process and service lines, instruments and controls, equipment, and data necessary for the design groups. The process flow diagram is the primary source of information for developing the P&ID. Symbols suitable for P&ID's are given in charts 5.1 thru 5.7.

The P&ID should define piping, equipment and instrumentation well enough for cost estimation and for subsequent design, construction, operation and modification of the process. Material balance data, flow rates, temperatures, pressures, etc., and piping fitting details are not shown, and purely mechanical piping details such as elbows, joints and unions are inappropriate to P&ID's.

### INTERCONNECTING P&ID

This drawing shows process and service lines between buildings and units, etc., and serves to link the P&ID's for the individual processes, units or buildings. Like any P&ID, the drawing is not to scale. It resembles the layout of the site plan, which enables line sizes and branching points from headers to be established, and assists in planning pipeways.

### P&ID LAYOUT

The layout of the P&ID should resemble as far as practicable that of the process flow diagram. The process relationship of equipment should correspond exactly. Often it is useful to draw equipment in proportion vertically, but to reduce horizontal dimensions to save space and allow room for flow lines between equipment. Crowding information is a common drafting fault — it is desirable to space generously, as, more often than not, revisions add information. On an elevational P&ID, a base line indicating grade or first-floor level can be shown. Critical elevations are noted.

For revision purposes, a P&ID is best made on a drawing sheet having a grid system—this is a sheet having letters along one border and numbers along the adjacent border. Thus, references such as 'A6', 'B5', etc., can be given to an area where a change has been made. (A grid system is applicable to P&ID's more complicated than the simple example of figure 5.4.)

### DRAFTING GUIDELINES FOR P&ID's

- Suitable line thicknesses are shown at full size in chart 5.1
- Crossing lines must not touch—break lines going in one direction only. Break instrument lines crossing process and service lines
- Keep parallel lines at least 3/8 inch apart
- Preferably draw all valves the same size—1/4-inch long is suitable—as this retains legibility for photographic reduction. Instrument isolating valves and drain valves can be drawn smaller, if desired
- Draw instrument identification balloons 7/16th-inch diameter—see 5.5
- Draw trap symbols 3/8th-inch square

### FLOW LINES ON P&ID's

All flow lines and interconnections should be shown on P&ID's. Every line should show direction of flow, and be labeled to show the area of project, conveyed fluid, line size, piping material or specification code number (company code), and number of the line. This information is shown in the 'line number'.

**EXAMPLE LINE NUMBER:** **(74|BZ|6|412|23)** may denote the 23rd line in area 74, a 6-inch pipe to company specification 412. 'BZ' identifies the conveyed fluid.

This type of full designation for a flow line need not be used, provided identification is adequate.

Piping drawings use the line numbering of the P&ID, and the following points apply to piping drawings as well as P&ID's.

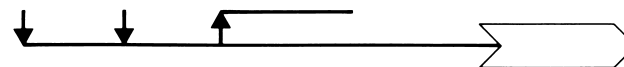
- For a system of lines conveying the same fluid, allocate sequential numbers to lines, beginning with '1' *for each system*
- For a continuous line, retain the same number of line (such as 23 in the example) as the line goes thru valves, strainers, small filters, traps, venturis, orifice flanges and small equipment generally —unless the line changes in size
- Terminate the number of a line at a major item of equipment such as a tank, pressure vessel, mixer, or any equipment carrying an individual equipment number
- Allocate new numbers to branches



As with the process flow diagram, directions of flow within the drawing are shown by solid arrows placed at every junction, and all corners except where changes of direction occur closely together. Corners should be square. The number of crossings should be kept minimal by good arrangement.

Process and service streams entering or leaving the process are noted by hollow arrows with the name of the conveyed fluid written over the arrowhead and the continuation sheet number within it. No process flow data will normally be shown on a P&ID.

### FLOW LINES ON P&ID's



### NOTES FOR LINES

Special points for design and operating procedures are noted—such as lines which need to be sloped for gravity flow, lines which need careful cleaning before startup, etc.

Temporary closures for process operation or personnel protection are shown.

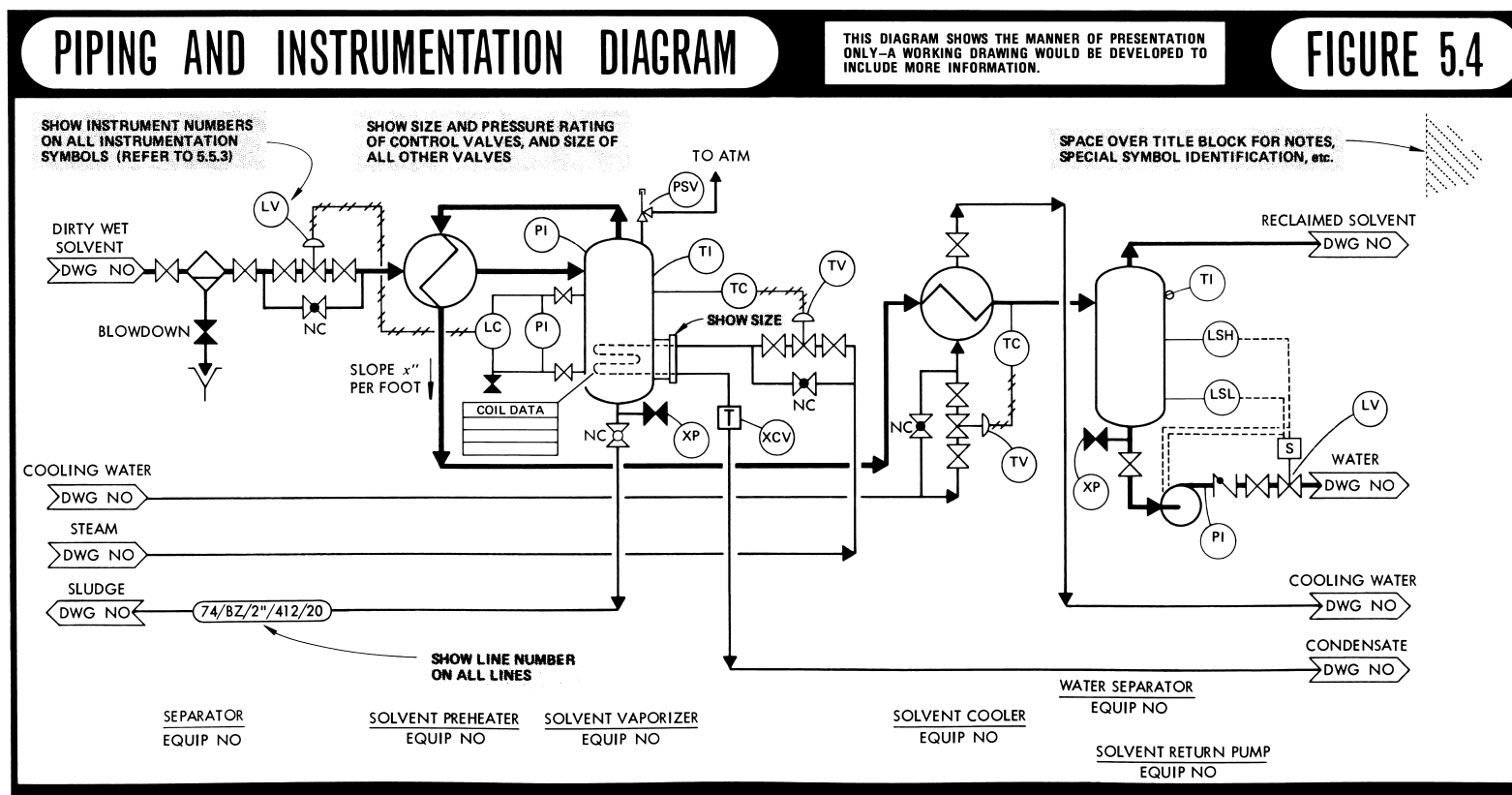
These items should be shown upstream of equipment and processes needing protection, and are discussed in 2.10.

If the locations of traps are known they are indicated. For example, the trap required upstream of a pressure-reducing station feeding a steam turbine should be shown.

Steam traps on steam piping are not otherwise indicated, as these trap positions are determined when making the piping drawings. They can be added later to the P&ID if desired, after the piping drawings have been completed.

Driplegs are not shown.

Vents and drains on high and low points of lines respectively, to be used for hydrostatic testing, are not shown, as they are established on the piping arrangement drawings. Process vents and drains are shown.



## VALVES ON THE P&ID

- Show and tag process and service valves with size and identifying number if applicable. Give pressure rating if different from line specification
- Indicate any valves that have to be locked open or locked closed
- Indicate powered operators

## SHOWING INSTRUMENTATION ON THE P&ID

Signal-lead drafting symbols shown in chart 5.1 may be used, and the ISA scheme for designating instrumentation is described in 5.5. Details of instrument piping and conduit are usually shown on separate instrument installation drawings.

- Show all instrumentation on the P&ID, for and including these items: element or sensor, signal lead, orifice flange assembly, transmitter, controller, vacuum breaker, flame arrestor, level gage, sight glass, flow indicator, relief valve, rupture disc, safety valve. The last three items may be tagged with set pressure(s) also
- Indicate local- or board-mounting of instruments by the symbol—refer to the labeling scheme in 5.5.4

## INSULATION & TRACING

Insulation on piping and equipment is shown, together with the thickness required. Tracing requirements are indicated. Refer to 6.8.

## CONTROL STATIONS

Control stations are discussed in 6.1.4. Control valves are indicated by pressure rating, instrument identifying number and size—see figure 5.15, for example.

## P&ID SHOWS HOW WASTES ARE HANDLED

Drains, funnels, relief valves and other equipment handling wastes are shown on the P&ID. If an extensive system or waste-treatment facility is involved, it should be shown on a separate P&ID. Wastes and effluents are discussed in 6.13.

## SERVICE SYSTEMS MAY HAVE THEIR OWN P&ID

Process equipment may be provided with various services, such as steam for heating, water or refrigerant for cooling, or air for oxidizing. Plant or equipment providing these services is usually described on separate 'service P&ID's'. A service line such as a steam line entering a process P&ID is given a 'hollow arrow' line designation taken from the service P&ID. Returning service lines are designated in the same way. Refer to figure 5.4.

## UTILITY STATIONS

Stations providing steam, compressed air, and water, are shown. Refer to 6.1.5.

## LINE DESIGNATION SHEETS OR TABLES

5.2.5

These sheets are tabulated lists of lines and information about them. The numbers of the lines are usually listed at the right of the sheet. Other columns list line size, material of construction (using company's specification code, if there is one), conveyed fluid, pressure, temperature, flow rate, test pressure, insulation or jacketing (if required), and connected lines (which will usually be branches).

The sheets are compiled and kept up-to-date by the project group, taking all the information from the P&ID. Copies are supplied to the piping group for reference.

On small projects involving only a few lines line designation sheets may not be used. It is useful to add a note on the P&ID stating the numbers of the last line and last valve used.

## VIEWS USED FOR PIPING DRAWINGS

5.2.6

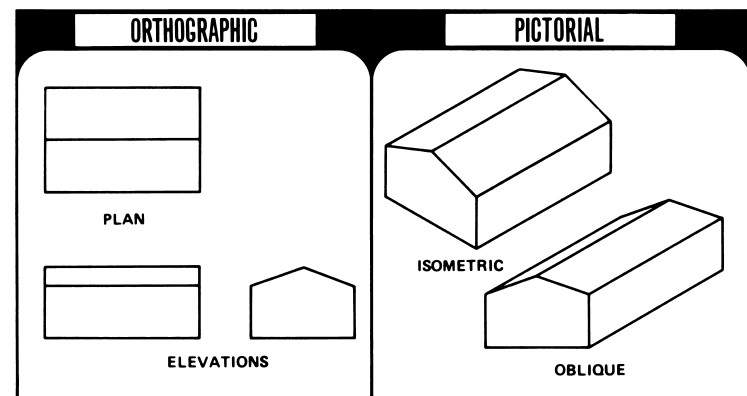
Two types of view are used:

- (1) **ORTHOGRAPHIC – PLANS AND ELEVATIONS**
- (2) **PICTORIAL – ISOMETRIC VIEW AND OBLIQUE PRESENTATION**

Figure 5.5 shows how a building would appear in these different views.

## PRESENTATIONS USED IN PIPING DRAWINGS

FIGURE 5.5



## PLANS & ELEVATIONS

Plan views are more common than elevational views. Piping layout is developed in plan view, and elevational views and section details are added for clarity where necessary.

## PICTORIAL VIEWS

In complex piping systems, where orthographic views may not easily illustrate the design, pictorial presentation can be used for clarity. In either isometric or oblique presentations, lines not horizontal or vertical on the drawing are usually drawn at 30 degrees to the horizontal.

Oblique presentation has the advantage that it can be distorted or expanded to show areas of a plant, etc. more clearly than an isometric view. It is not commonly used, but can be useful for diagrammatic work.

Figure 5.6 illustrates how circular shapes viewed at different angles are approximated by means of a 35-degree ellipse template. Isometric templates for valves, etc., are available and neat drawings can be rapidly produced with them. Orthographic and isometric templates can be used to produce an oblique presentation.

#### ISOMETRIC PRESENTATION OF CIRCULAR SECTIONS

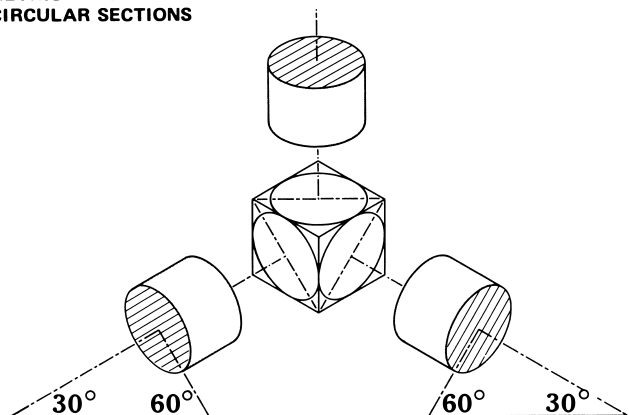


FIGURE 5.6

#### PLAN, ELEVATION, ISOMETRIC & OBLIQUE PRESENTATIONS OF A PIPING SYSTEM

Figure 5.7 is used to show the presentations used in drafting. Isometric and oblique drawings both clearly show the piping arrangement, but the plan view fails to show the bypass loop and valve, and the supplementary elevation is needed.

#### PIPING DRAWINGS ARE BASED ON OTHER DRAWINGS

5.2.7

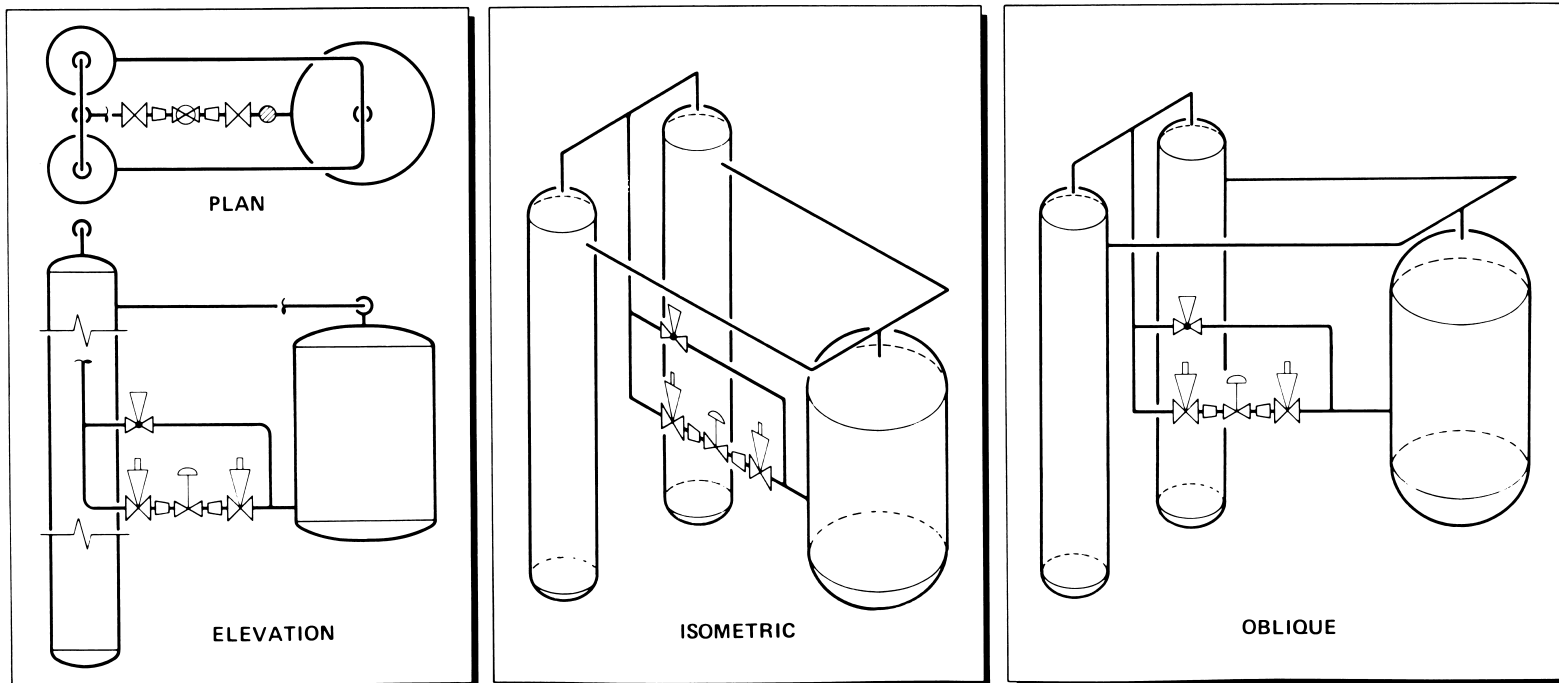
The purpose of piping drawings is to supply detailed information to enable a plant to be built. Prior to making piping drawings, the site plan and equipment arrangement drawings are prepared, and from these two drawings the plot plan is derived. These three drawings are used as the basis for developing the piping drawings.

#### SITE PLAN

The piping group produces a 'site plan' to a small scale (1 inch to 30 or 100 ft for example). It shows the whole site including the boundaries, roads, railroad spurs, pavement, buildings, process plant areas, large structures, storage areas, effluent ponds, waste disposal, shipping and loading areas. 'True' (geographic) and 'assumed' or 'plant' north are marked and their angular separation shown—see figure 5.11.

#### PIPING ARRANGEMENT IN DIFFERENT PRESENTATIONS

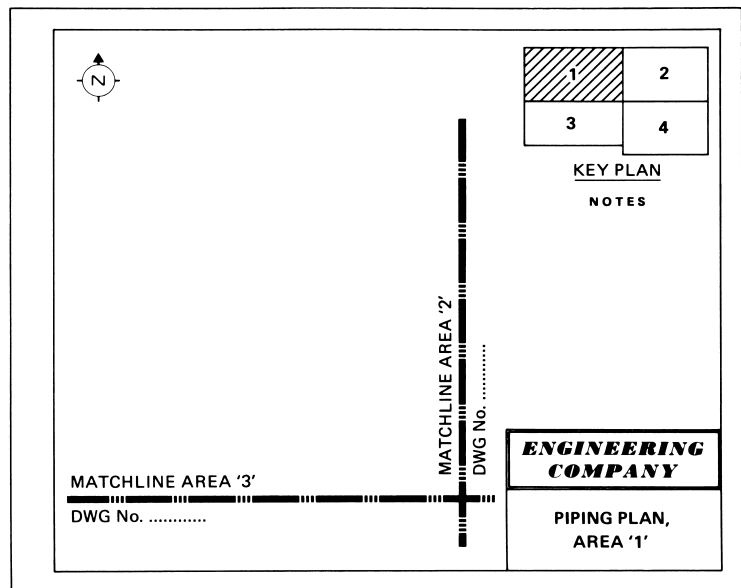
FIGURE 5.7



A 'key plan' is produced by adapting the site plan, dividing the area of the site into smaller areas identified by key letters or numbers. A small simplified inset of the key plan is added to plot plans, and may be added to piping and other drawings for reference purposes. The subject area of the particular drawing is hatched or shaded, as shown in figure 5.8.

**DRAWING SHEET SHOWING KEY PLAN & MATCHLINE**

**FIGURE 5.8**



### EQUIPMENT ARRANGEMENT DRAWING

Under project group supervision, the piping group usually makes several viable arrangements of equipment, seeking an optimal design that satisfies process requirements. Often, preliminary piping studies are necessary in order to establish equipment coordinates.

A design aid for positioning equipment is to cut out scaled outlines of equipment from stiff paper, which can be moved about on a plan view of the area involved. (If multiple units of the same type are to be used, xeroxing the equipment outlines is faster.) Another method which is useful for areas where method study or investigational reports are needed is described in 4.4.13 under 'Photographic layouts'.

### PLOT PLAN

When the equipment arrangement drawings are approved, they are developed into 'plot plans' by the addition of dimensions and coordinates to locate all major items of equipment and structures.

North and east coordinates of the extremities of buildings, and centerlines of steelwork or other architectural constructions should be shown on the plot plan, preferably at the west and south ends of the installation. Both 'plant north' and true north should be shown—see figure 5.11.

Equipment coordinates are usually given to the centerlines. Coordinates for pumps are given to the centerline of the pump shaft and either to the face of the pump foundation, or to the centerline of the discharge port.

Up-dated copies of the above drawings are sent to the civil, structural and electrical or other groups involved in the design, to inform them of requirements as the design develops.

### VESSEL DRAWINGS

When the equipment arrangement has been approved and the piping arrangement determined, small dimensioned drawings of process vessels are made (on sheets 8½ x 11 or 11 x 17 inches) in order to fix nozzles and their orientations, manholes, ladders, etc. These drawings are then sent to the vendor who makes the shop detail drawings, which are examined by the project engineer and sent to the piping group for checking and approval. Vessel drawings need not be to scale. (Figure 5.14 is an example vessel drawing.)

### DRAWINGS FROM OTHER SOURCES

Piping drawings should be correlated with the following drawings from other design groups and from vendors. Points to be checked are listed:

#### *Architectural drawings:*

- Outlines of walls or sidings, indicating thickness
- Floor penetrations for stairways, lifts, elevators, ducts, drains, etc.
- Positions of doors and windows

#### *Civil engineering drawings:*

- Foundations, underground piping, drains, etc.

#### *Structural-steel drawings:*

- Positions of steel columns supporting next higher floor level
- Supporting structures such as overhead cranes, monorails, platforms or beams
- Wall bracing, where pipes may be taken thru walls

#### *Heating, ventilating & air-conditioning (HVAC) drawings:*

- Paths of ducting and rising ducts, fan room, plenums, space heaters, etc.

#### *Electrical drawings:*

- Positions of motor control centers, switchgear, junction boxes and control panels
- Major conduit or wiring runs (including buried runs)
- Positions of lights

#### *Instrumentation drawings:*

- Instrument panel and console locations

#### *Vendors' drawings:*

- Dimensions of equipment
- Positions of nozzles, flange type and pressure rating, instruments, etc.

#### *Mechanical drawings:*

- Positions and dimensions of mechanical equipment such as conveyors, chutes, etc.
- Piped services needed for mechanical equipment.

## PIPING DRAWINGS

### 5.2.8

Process equipment and piping systems have priority. Drawings listed on the preceding page must be reviewed for compatibility with the developing piping design.

Pertinent background details (drawn faintly) from these drawings help to avoid interferences. Omission of such detail from the piping drawing often leads to the subsequent discovery that pipe has been routed thru a brace, stairway, doorway, foundation, duct, mechanical equipment, motor control center, fire-fighting equipment, etc.

Completed piping drawings will also show spool numbers, if this part of the job is not subcontracted — see 5.2.9. Electrical and instrument cables are not shown on piping drawings, but trays to hold the cables are indicated—for example, see figure 6.3, point (8).

It is not always possible for the piping drawing to follow exactly the logical arrangement of the P&ID. Sometimes lines must be routed with different junction sequence, and line numbers may be changed. During the preliminary piping studies, economies and practicable improvements may be found, and the P&ID may be modified to take these into account. However, it is not the piping designer's job to seek ways to change the P&ID.

## SCALE

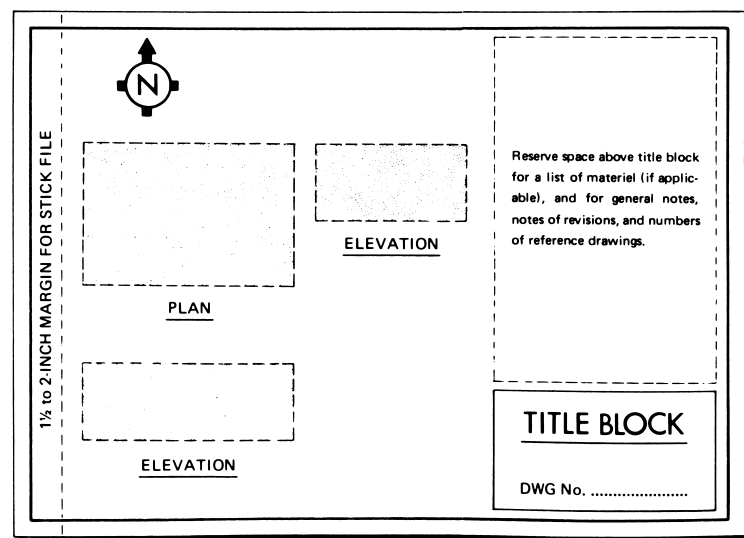
Piping is arranged in plan view, usually to 3/8 in./ft scale.

## ALLOCATING SPACE ON THE SHEET

- Obtain the drawing number and fill in the title block at the bottom right corner of the sheet

## ALLOCATING SPACE ON A DRAWING SHEET

FIGURE 5.9



- On non-standard sheets, leave a 1½- to 2-inch margin at the left edge of the sheet, to allow filing on a 'stick'. Standard drawing sheets usually have this margin
- On drawings showing a plan view, place a north arrow at the top left corner of the sheet to indicate plant north—see figure 5.11
- Do not draw in the area above the title block, as this space is allocated to the bill of material, or to general notes, brief descriptions of changes, and the titles and numbers of reference drawings
- If plans and elevations are small enough to go on the same sheet, draw the plan at the upper left side of the sheet and elevations to the right and bottom of it, as shown in figure 5.9

## BACKGROUND DETAIL

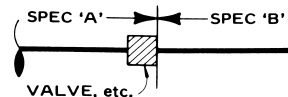
- Show background detail as discussed in 5.2.8 under 'Piping drawings'. It is sometimes convenient to draw outlines on the reverse side of the drawing sheet
- After background details have been determined, it is best to make a print on which nozzles on vessels, pumps, etc., to be piped can be marked in red pencil. Utility stations can also be established. This will indicate areas of major usage and the most convenient locations for the headers. Obviously, at times there will be a number of alternate routes offering comparable advantages

## PROCESS & SERVICE LINES ON PIPING DRAWINGS

- Take line numbers from the P&ID. Refer to 5.2.4 under 'Flow lines on P&ID's' for information on numbering lines. Include line numbers on all views, and arrowheads showing direction of flow
- Draw all pipe 'single line' unless special instructions have been given for drawing 'double line'. Chart 5.1 gives line thicknesses (full size)
- Line numbers are shown against lines, thus:



- Take lines continued on another sheet to a matchline, and there code with line numbers only. Show the continuation sheet numbers on matchlines—see figure 5.8
- Show where changes in line material specification occur. The change is usually indicated immediately downstream of a flange of a valve or equipment



- Show a definite break in a line crossing behind another line—see 'Rolled ell', under 'Plan view piping drawings', this section

- If pipe sleeves are required thru floors, indicate where they are needed and inform the group leader for transmitting this information to the group(s) concerned
- Indicate insulation, and show whether lines are electrically or steam traced—see chart 5.7

#### FITTINGS, FLANGES, VALVES & PUMPS ON PIPING DRAWINGS

- The following items should be labeled in one view only: tees and ells rolled at 45 degrees (see example, this page), short-radius ell, reducing ell, eccentric reducer and eccentric swage (note on plan views whether 'top flat' or 'bottom flat'), concentric reducer, concentric swage, non-standard or companion flange, reducing tee, special items of unusual material, of pressure rating different from that of the system, etc. Refer to charts 5.3, 5.4 and 5.5 for symbol usage
- Draw the outside diameters of flanges to scale
- Show valve identification number from P&ID
- Label control valves to show: size, pressure rating, dimension over flanges, and valve instrument number, from the P&ID—see figure 5.15
- Draw valve handwheels to scale with valve stem fully extended
- If a valve is chain-operated, note distance of chain from operating floor, which for safety should be approximately 3 ft
- For pumps, show outline of foundation and nozzles

#### DRIPLEGS & STEAM TRAPS

Driplegs are indicated on relevant piping drawing plan views. Unless identical, a separate detail is drawn for each dripleg. The trap is indicated on the dripleg piping by a symbol, and referred to a separate trap detail or data sheet. The trap detail drawing should show all necessary valves, strainers, unions, etc., required at the trap—see figures 6.43 and 6.44.

The piping shown on the dripleg details should indicate whether condensate is to be taken to a header for re-use, or run to waste. The design notes in 6.10.5 discuss dripleg details for steam lines in which condensate forms continuously. Refer to 6.10.9 also.

#### INSTRUMENTS & CONNECTIONS ON PIPING DRAWINGS

- Show location for each instrument connection with encircled instrument number taken from the P&ID. Refer to 5.5.3 and chart 6.2
- Show similar isolating valve arrangements on instrument connections as 'typical' detail, unless covered by standard company detail sheet

#### VENTS & DRAINS

Refer to 6.11 and figure 6.47.

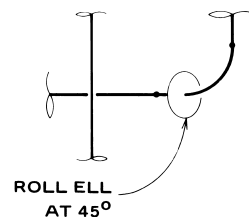
#### PIPE SUPPORTS

Refer to 6.2.2, and chart 5.7. for symbols.

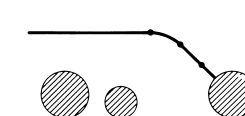
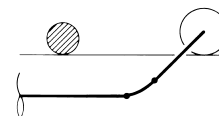
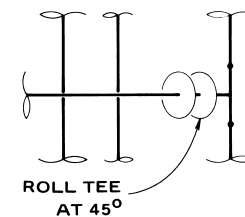
#### PLAN VIEW PIPING DRAWINGS

- Draw plan views for each floor of the plant. These views should show what the layout will look like between adjacent floors, viewed from above, or at the elevation thru which the plan view is cut
- If the plan view will not fit on one sheet, present it on two or more sheets, using matchlines to link the drawings. See figure 5.8
- Note the elevation below which a plan view is shown—for example, 'PLAN BELOW ELEVATION 15'–0" '. For clarity, both elevations can be stated: 'PLAN BETWEEN ELEVATIONS 30'–0" & 15'–0" '
- If a tee or elbow is 'rolled' at 45 degrees, note as shown in the view where the fitting is rolled out of the plane of the drawing sheet

'ROLLED' ELL



'ROLLED' TEE



- Figure 5.10 shows how lines can be broken to give sufficient information without drawing other views
- Indicate required field welds

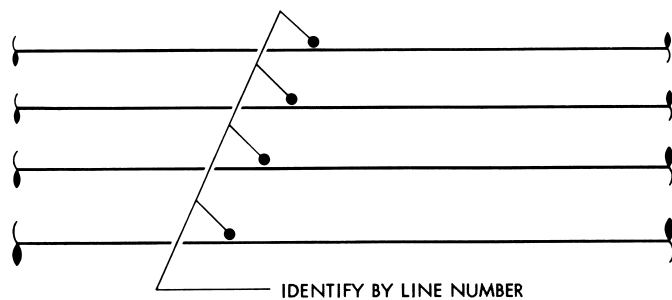
#### ELEVATIONS (SECTIONS) & DETAILS

- Draw elevations and details to clarify complex piping or piping hidden in the plan view
- Do not draw detail that can be described by a note
- Show only as many sections as necessary. A section does not have to be a complete cross section of the plan
- Draw to a large scale any part needing fuller detail. Enlarged details are preferably drawn in available space on elevational drawings, and should be cross-referenced by the applicable detail and drawing number(s)
- Identify sections indicated on plan views by letters (see chart 5.8) and details by numbers. Letters I and O are not used as this can lead to confusion with numerals. If more than twentyfour sections are needed the letter identification can be broken down thus: A1–A1, A2–A2, B4–B4, ..... and so on
- Do not section plan views looking toward the bottom of the drawing sheet

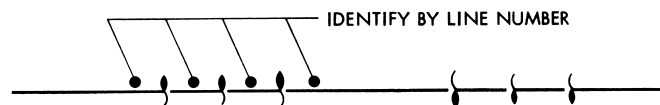
- Figure 5.10 shows how to break lines to give sufficient information whilst avoiding drawing another view or section

#### SHOWING 'HIDDEN' LINES ON PIPING DRAWINGS

FIGURE 5.10



P L A N (or ELEVATION)



Corresponding ELEVATION (or PLAN)

#### PIPING FABRICATION DRAWINGS—'ISOS' & 'SPOOLS'

5.2.9

The two most common methods for producing piping designs for a plant are by making either plan and elevation drawings, or by constructing a scaled model. For fabricating welded piping, plans and elevations are sent directly to a subcontractor, usually referred to as a 'shop fabricator'—if a model is used, isometric drawings (referred to as 'isos') are sent instead.

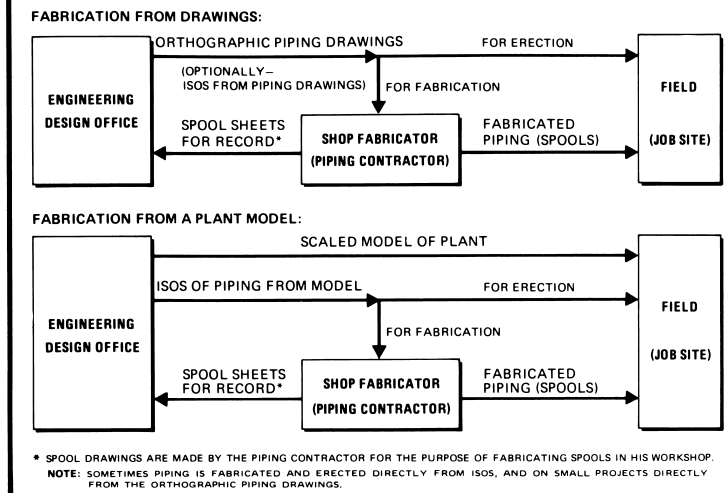
Isometric views are commonly used in prefabricating parts of butt-welded piping systems. Isos showing the piping to be prefabricated are sent to the shop fabricator. Figure 5.15 is an example of such an iso.



The prefabricated parts of the piping system are termed 'spools', described under 'Spools', this section. The piping group either produces isos showing the required spools, or marks the piping to be spooled on plans and elevations, depending on whether or not a model is used (as shown in chart 5.10). From these drawings, the subcontractor makes detail drawings termed 'spool sheets'. Figure 5.17 is an example spool sheet.

#### SPOOL FABRICATION

CHART 5.10



#### ISOMETRIC DRAWINGS, or 'ISOS'

An iso usually shows a complete line from one piece of equipment to another—see figure 5.15. It gives all information necessary for fabrication and erection of piping.

Isos are usually drawn freehand, but the various runs of pipe, fittings and valves should be roughly in proportion for easy understanding. Any one line (that is, all the piping with the same line number) should be drawn on the minimum number of iso sheets. If continuation sheets are needed, break the line at natural breakpoints such as flanges (except orifice flanges), welds at fittings, or field welds required for installation.

Items and information to be shown on an iso include:

- North arrow (plant north)
- Dimensions and angles
- Reference number of plan drawing from which iso is made (unless model is used), line number, direction of flow, insulation and tracing
- Equipment numbers and locations of equipment (by centerlines)
- Identify all items by use of an understood symbol, and amplify by a description, as necessary
- Give details of any flanged nozzles on equipment to which piping has to be connected, if the flange is different from the specification for the connected piping
- Size and type of every valve
- Size, pressure rating and instrument number of control valves
- Number, location and orientation for each instrument connection

- Shop and field welds. Indicate limits of shop and field fabrication
- Iso sheet continuation numbers
- Unions required for installation and maintenance purposes
- On screwed and socket-welded assemblies, valve handwheel positions need not be shown
- Materials of construction
- Locations of vents, drains, and traps
- Locations of supports, identified by pipesupport number

The following information may also be given:

- Requirements for stress relieving, seal welding, pickling, lining, coating, or other special treatment of the line

Drawing style to be followed is shown in the example iso, figure 5.15, which displays some of the above points, and gives others as shaded notes. An iso may show more than one spool.

## SPOOLS

A spool is an assembly of fittings, flanges and pipe that may be prefabricated. It does not include bolts, gaskets, valves or instruments. Straight mill-run lengths of pipe over 20 ft are usually not included in a spool, as such lengths may be welded in the system on erection (on the iso, this is indicated by noting the length, and stating 'BY FIELD').

The size of a spool is limited by the fabricator's available means of transportation, and a spool is usually contained within a space of dimensions 40 ft x 10 ft x 8 ft. The maximum permissible dimensions may be obtained from the fabricator.

## FIELD-FABRICATED SPOOLS

Some States in the USA have a trades agreement that 2-inch and smaller carbon-steel piping must be fabricated at the site. This rule is sometimes extended to piping larger than 2-inch.

## SHOP-FABRICATED SPOOLS

All alloy spools, and spools with 3 or more welds made from 3-inch (occasionally 4-inch) and larger carbon-steel pipe are normally 'shop-fabricated'. This is, fabricated in the shop fabricator's workshop, either at his plant or at the site. Spools with fewer welds are usually made in the field.

Large-diameter piping, being more difficult to handle, often necessitates the use of jigs and templates, and is more economically produced in a workshop.

## SPOOL SHEETS

A spool sheet is an orthographic drawing of a spool made by the piping contractor either from plans and elevations, or from an iso—see chart 5.10.

Each spool sheet shows only one type of spool, and:—

- (1) Instructs the welder for fabricating the spool
- (2) Lists the cut lengths of pipe, fittings and flanges, etc. needed to make the spool
- (3) Gives materials of construction, and any special treatment of the finished piping
- (4) Indicates how many spools of the same type are required

## NUMBERING ISOS, SPOOL SHEETS, & SPOOLS

Spool numbers are allocated by the piping group, and appear on all piping drawings. Various methods of numbering can be used as long as identification is easily made. A suggested method follows:—

Iso sheets can be identified by the line number of the section of line that is shown, followed by a sequential number. For example, the fourth iso sheet showing a spool to be part of a line numbered 74/BZ/6/412/23 could be identified: 74/BZ/6/412/23—4 .



Both the spool and the spool sheet can be identified by number or letter using the iso sheet number as a prefix. For example, the numbering of spool sheets relating to iso sheet 74/BZ/6/412/23—4 could be

74/BZ/6/412/23—4—1, 74/BZ/6/412/23—4—2, ..... etc.,  
or 74/BZ/6/412/23—4—A, 74/BZ/6/412/23—4—B, ..... etc.

The full line number need not be used if a shorter form would suffice for identification.

Spool numbers are also referred to as 'mark numbers'. They are shown on isos and on the following:—

- (1) Spool sheets—as the sheet number
- (2) The fabricated spool—so it can be related to drawings or isos
- (3) Piping drawings—plans and elevations

## DIMENSIONING

5.3

### DIMENSIONING FROM REFERENCE POINTS

5.3.1

#### HORIZONTAL REFERENCE

When a proposed plant site is surveyed, a geographic reference point is utilized from which measurements to boundaries, roads, buildings, tanks, etc., can be made. The geographic reference point chosen is usually an officially-established one.

The lines of latitude and longitude which define the geographic reference point are not used, as a 'plant north' (see figure 5.11) is established, parallel to structural steelwork. The direction closest to true north is chosen for the 'plant north'.

The coordinates of the southwest corner of the plant in figure 5.11, as referred to 'plant north', are N 110.00 and E 200.00.

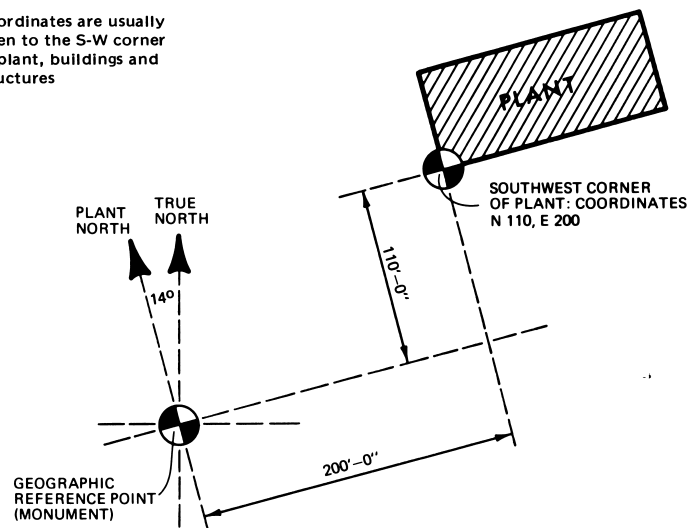
Sometimes coordinates such as those above may be written N 1+10 and E 2+00. The first coordinate is read as "one hundred plus 10 ft north" and the second as "two hundred plus zero ft east". This is a system used for traverse survey, and is more correctly applied to highways, railroads, etc.

Coordinates are used to locate tanks, vessels, major equipment and structural steel. In the open, these items are located directly with respect to a geographic reference point, but in buildings and structures, can be dimensioned from the building steel.

#### HORIZONTAL REFERENCE

FIGURE 5.11

Coordinates are usually given to the S-W corner of plant, buildings and structures



The US Department of Commerce's Coast and Geodetic Survey has established a large number of references for latitude and longitude, and for elevations above sea level. These are termed 'geodetic control stations'.

Control stations for horizontal reference (latitude and longitude) are referred to as 'triangulation stations' or 'traverse stations', etc. Control stations for vertical reference are referred to as 'benchmarks'. Latitude and longitude have not been established for all benchmarks.

A geodetic control station is marked with a metal disc showing identity and date of establishment. To provide stable locations for the discs, they are set into tops of 'monuments', mounted in holes drilled in bedrock or large firmly-imbedded boulders, or affixed to a solid structure, such as a building, bridge, etc.

The geographic positions of these stations can be obtained from the Director, US Coast and Geodetic Survey, Rockville, Maryland 20852.

#### VERTICAL REFERENCE

Before any building or erecting begins, the site is leveled ('graded') with earth-moving equipment. The ground is made as flat as practicable, and after leveling is termed 'finished grade'.

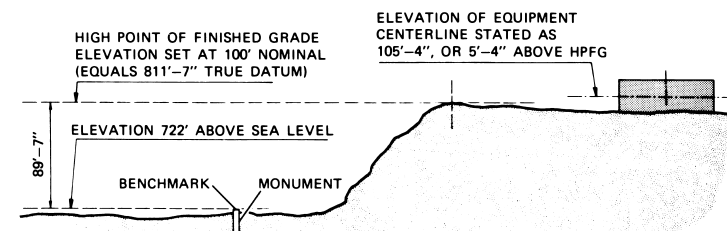
The highest graded point is termed the 'high point of finished grade', (HPFG), and the horizontal plane passing thru it is made the vertical reference plane or 'datum' from which plant elevations are given. Figure 5.12 shows that this horizontal plane is given a 'false' or nominal elevation, usually 100 ft, and is not referred to mean sea level.

The 100 ft nominal elevation ensures that foundations, basements, buried pipes and tanks, etc., will have positive elevations. 'Minus' elevations, which would be a nuisance, are thus avoided.

Large plants may have several areas, each having its own high point of finished grade. Nominal grade elevation is measured from a benchmark, as illustrated in figure 5.12.

#### VERTICAL REFERENCE

FIGURE 5.12



#### DIMENSIONING PIPING DRAWINGS

5.3.2

#### DRAWING DIMENSIONS—& TOLERANCES MAINTAINED IN ERECTED PIPING

**On plot:** Dimensions on piping drawings are normally maintained within the limits of plus or minus 1/16th inch. How this tolerance is met does not concern the designer. Any necessary allowances to ensure that dimensions are maintained are made by the fabricator and erector (contractor).

**Off plot:** Dimensions are maintained as closely as practicable by the erector.

#### WHICH DIMENSIONS SHOULD BE SHOWN?

Sufficient dimensions should be given for positioning equipment, for fabricating spools and for erecting piping. Duplication of dimensions in different views should be avoided, as this may easily lead to error if alterations are made.

Basically the dimensions to show are:

| TYPE OF DIMENSION  |                               | EXAMPLES  |
|--|-------------------------------|---|
| 1  | REFERENCE LINE* TO CENTERLINE | VESSELS<br>PUMPS<br>EQUIPMENT<br>LINES                      |
| 2  | CENTERLINE TO CENTERLINE      | LINES<br>STANDARD VALVES                                    |
| 3  | CENTERLINE TO FLANGE FACE †   | NOZZLES ON { VESSELS<br>PUMPS<br>EQUIPMENT                  |
| 4  | FLANGE FACE TO FLANGE FACE†   | NON-STANDARD { VALVES<br>EQUIPMENT<br>METERS<br>INSTRUMENTS |
| <p>* REFERENCE LINE CAN BE EITHER AN ORDINATE (LINE OF LATITUDE OR LONGITUDE) OR A CENTERLINE OF BUILDING STEEL</p> <p>† IT IS NECESSARY TO SHOW THESE DIMENSIONS FOR ITEMS LACKING STANDARD DIMENSIONS (DEFINED BY ANY RECOGNIZED STANDARD)</p> |                               |   |

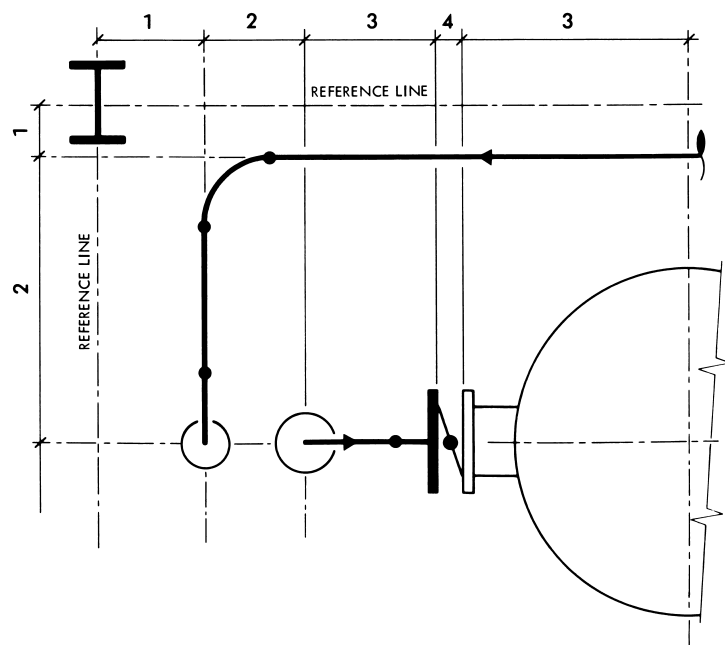
Figure 5.13 illustrates the use of these types of dimensions.

## PLAN VIEW DIMENSIONS

Plan views convey most of the dimensional information, and may also show dimensions for elevations in the absence of an elevational view or section.

### EXAMPLE DIMENSIONS FOR PLAN VIEW

FIGURE 5.13



## VERTICAL VIEW ELEVATIONS & DIMENSIONS

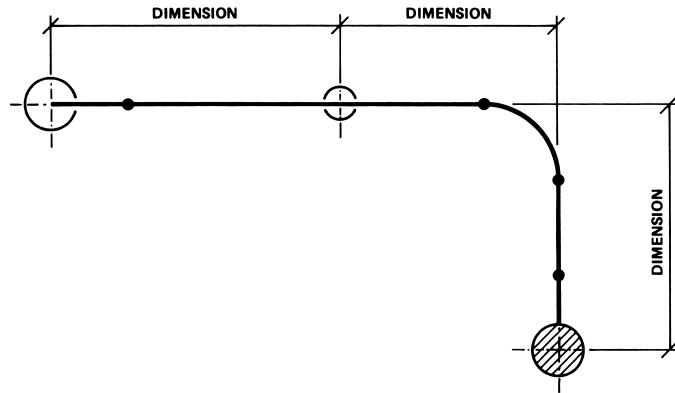
On piping drawings, elevations may be given as in table 5.2.

| SHOWING ELEVATIONS  |  | TABLE 5.2 |
|---|--|-----------|
| PIPE—GENERAL  | BURIED PIPE  |           |
| <p>SINGLE PIPE:<br/>SHOW CENTERLINE ELEVATION</p>   | <p>BURIED LINES (IN A TRENCH):<br/>SHOW ELEVATION OF BOTTOMS OF PIPES</p>  |           |
| <p>SINGLE PIPE TO NOZZLE: SHOW<br/>CENTERLINE ELEVATION OF<br/>PIPE AT NOZZLE</p>         | <p>FOR MINIMUM COVER, REFER TOP OF<br/>PIPE TO GRADE ELEVATION:</p>  |           |
| <p>SEVERAL PIPES SHARING A COMMON<br/>SUPPORT: SHOW ELEVATION OF<br/>BOTTOMS OF PIPES</p> | <p>DRAINS AND SEWERS:<br/>SHOW 'INVERT ELEVATION' (IE)</p>   |           |
| <p>SEVERAL PIPES ON A PIPERACK:<br/>SHOW 'TOP OF SUPPORT' ELEVATION</p>                   | <p>CLEARANCES:</p> <p>*PIPES MAY BE RUN UNDER GRADE BEAMS OF<br/>BUILDINGS, BUT NOT UNDER FOUNDATIONS.</p>             |           |
| MISCELLANEOUS ELEVATIONS  |  |           |
| <p>FINISHED FLOOR:<br/>SHOW ELEVATION OF HIGH POINT<br/>OF FLOOR</p>                      | <p>VERTICAL NOZZLE:<br/>SHOW ELEVATION OF FLANGE FACE</p>  |           |
| <p>FOUNDATION: SHOW 'TOP OF CONCRETE',<br/>INCLUDING GROUT</p>                            | <p>INSTRUMENT POINT: SHOW ELEVATION OF<br/>CONNECTION CENTERLINE, or DIMENSION<br/>FROM NEAREST RELEVANT ELEVATION</p> |           |
| <p>SHOE: DIMENSION AS SHOWN IN THE<br/>PIPERACK SKETCH ABOVE</p>                          |  |           |

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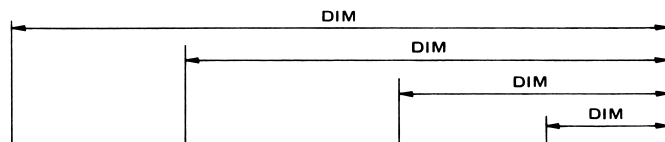
### GUIDELINES FOR DIMENSIONING ALL PIPING DRAWINGS 5.3.3

- Show all key dimensions, including elevations and coordinates
- Show dimensions outside of the drawn view unless unavoidable – do not clutter the picture
- Draw dimension lines unbroken with a fine line. Write the dimension just above a horizontal line. Write the dimension of a vertical line sideways, preferably at the left. It is usual to terminate the line with arrowheads, and these are preferable for isos. The oblique dashes shown are quicker and are suitable for plans and elevations, especially if the dimensions are cramped

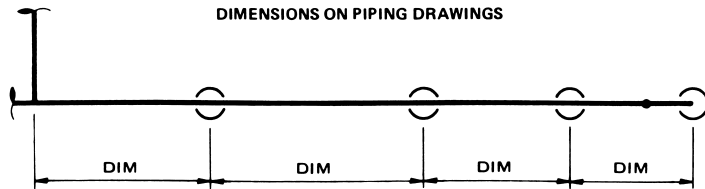


- If a series of dimensions is to be shown, string them together as shown in the sketch. (Do not dimension from a common reference line as in machine drawing.) Show the overall dimension of the string of dimensions if this dimension will be of repeated interest

DIMENSIONS ON MACHINE DRAWINGS



DIMENSIONS ON PIPING DRAWINGS



- Do not omit a *significant* dimension other than 'fitting makeup', even though it may be easily calculated – see 'fitting makeup', this section

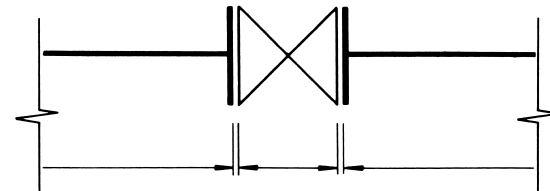
- Most piping under 2-inch is screwed or socket-welded and assembled at the site (field run). Therefore, give only those dimensions necessary to route such piping clear of equipment, other obstructions, and thru walls, and to locate only those items whose safe positioning or accessibility is important to the process
- Most lengths will be stated to the nearest sixteenth of an inch. Dimensions which cannot or need not be stated to this precision are shown with a plus-or-minus sign: 8'-7"±, 15'-3"±, etc.
- Dimensions under two feet are usually marked in inches, and those over two feet in feet and inches. Some companies prefer to mark all dimensions over one foot in feet and inches
- Attempt to round off non-critical dimensions to whole feet and inches. Reserve fractions of inches for dimensions requiring this precision

### PLANS & ELEVATIONS—GENERAL DIMENSIONING POINTS

- Reserve horizontal dimensions for the plan view
- Underline all out-of-scale dimensions, or show as in chart 5.8
- If a certain piping arrangement is repeated on the same drawing, it is sufficient to dimension the piping in one instance and note the other appearances as 'TYP' (typical). This situation occurs where similar pumps are connected to a common header. For another example, see the pump base in figure 6.17
- Do not duplicate dimensions. Do not repeat them in different views

### DIMENSIONING TO JOINTS

- Do not terminate dimensions at a welded or screwed joint
- Unless necessary, do not dimension to unions, in-line couplings or any other items that are not critical to construction or operation of the piping
- Where flanges meet it is usual to show a small gap between dimension lines to indicate the gasket. Gaskets should be covered in the piping specification, with gasket type and thickness stated. Refer to the panel 'Drafting valves', preceding chart 5.6.



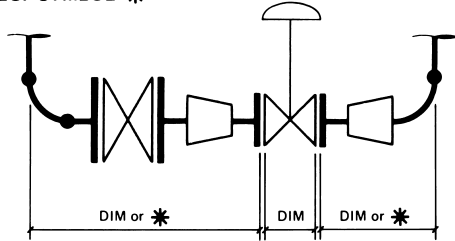
- As nearly all flanged joints have gaskets, a time-saving procedure is to note flanged joints without gaskets (for example, see 3.1.6 under 'Butterfly valve'). The fabricator and erector can be alerted to the need for gaskets elsewhere by a general note on all piping drawings:

"GASKETS AS SPECIFICATION EXCEPT AS NOTED"

## FITTING MAKEUP

If a number of items of standard dimensions are grouped together it is unnecessary to dimension each item, as the fabricator knows the sizes of standard fittings and equipment. It is necessary, however, to indicate that the overall dimension is 'fitting makeup' by the special cross symbol, or preferably by writing the overall dimension. Any non-standard item inserted between standard items should be dimensioned.

### FITTING MAKEUP SYMBOL \*



## DIMENSIONING TO VALVES

- Locate flanged and welding-end valves with ANSI standard dimensions by dimensioning to their centers. Most gate and globe valves are standard—see table V-1
- Dimension non-standard flanged valves as shown in the panel opposite chart 5.6. Although a standard exists for control valves, face-to-face dimensions are usually given, as it is possible to obtain them in non-standard sizes
- Standard flanged check valves need not be dimensioned, but if location is important, dimension to the flange face(s)
- Non-flanged valves are dimensioned to their centers or stems

## DIMENSIONING TO NOZZLES ON VESSELS & EQUIPMENT

- In plan view, a nozzle is dimensioned to its face from the centerline of the equipment it is on
- In elevation, a nozzle's centerline is either given its own elevation or is dimensioned from another reference. In the absence of an elevational view, nozzle elevations can be shown on the plan view

## DIMENSIONING ISOS

### 5.3.4

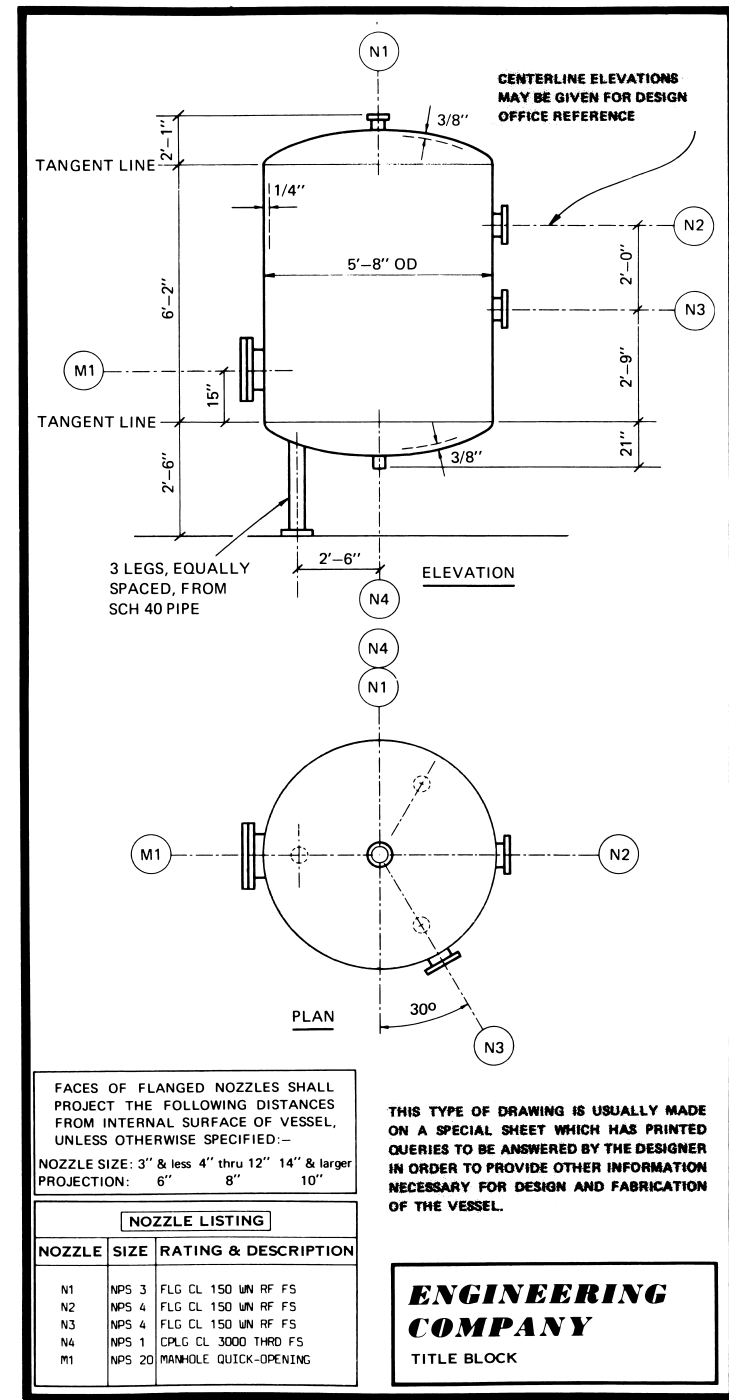
In order to clearly show all dimensions, the best aspect of the piping must be determined. Freedom to extend lines and spread the piping without regard to scale is a great help in showing isometric dimensions. The basic dimensions set out in 5.3.2, 5.3.3, and the guidelines in 5.2.9 apply.

Figure 5.15 illustrates the main requirements of an isometric drawing, and includes a dimensioned offset. Figure 5.16 shows how other offsets are dimensioned.

- Dimension in the same way as plans and elevations
- Give sufficient dimensions for the fabricator to make the spool drawings—see figure 5.17

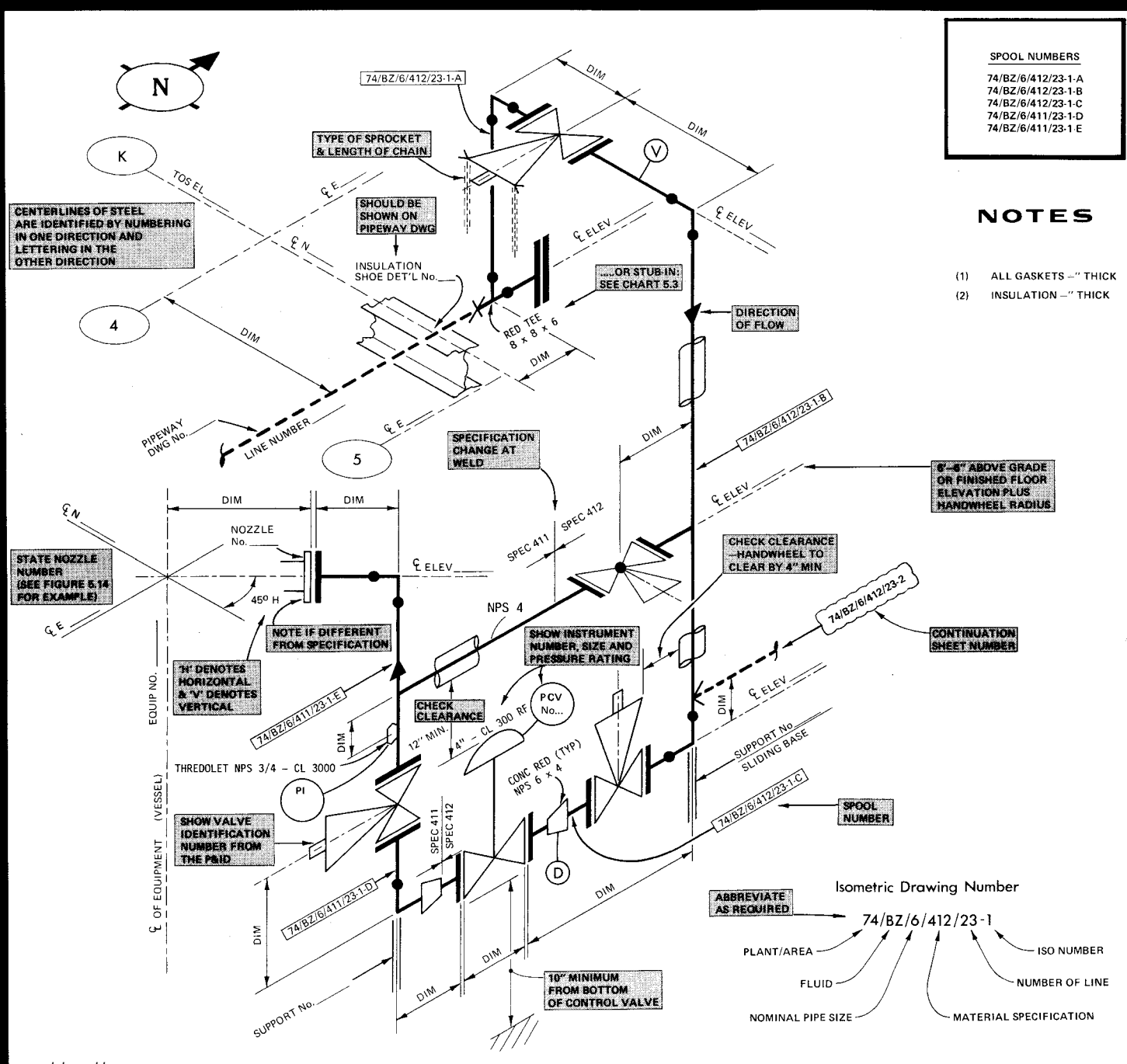
## EXAMPLE VESSEL DRAWING SHOWING DIMENSIONS REQUIRED BY VENDOR (Refer to 5.2.7)

FIGURE 5.14



**EXAMPLE 'ISO'**

**FIGURE 5.15**



HOW TO SHOW OFFSETS ON ISOS

(Chart M-1 gives a formula for calculating the compound angle)

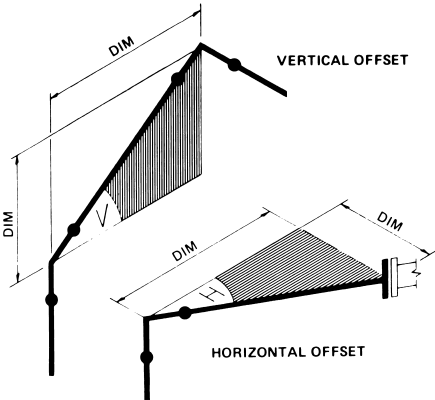


FIGURE 5.16

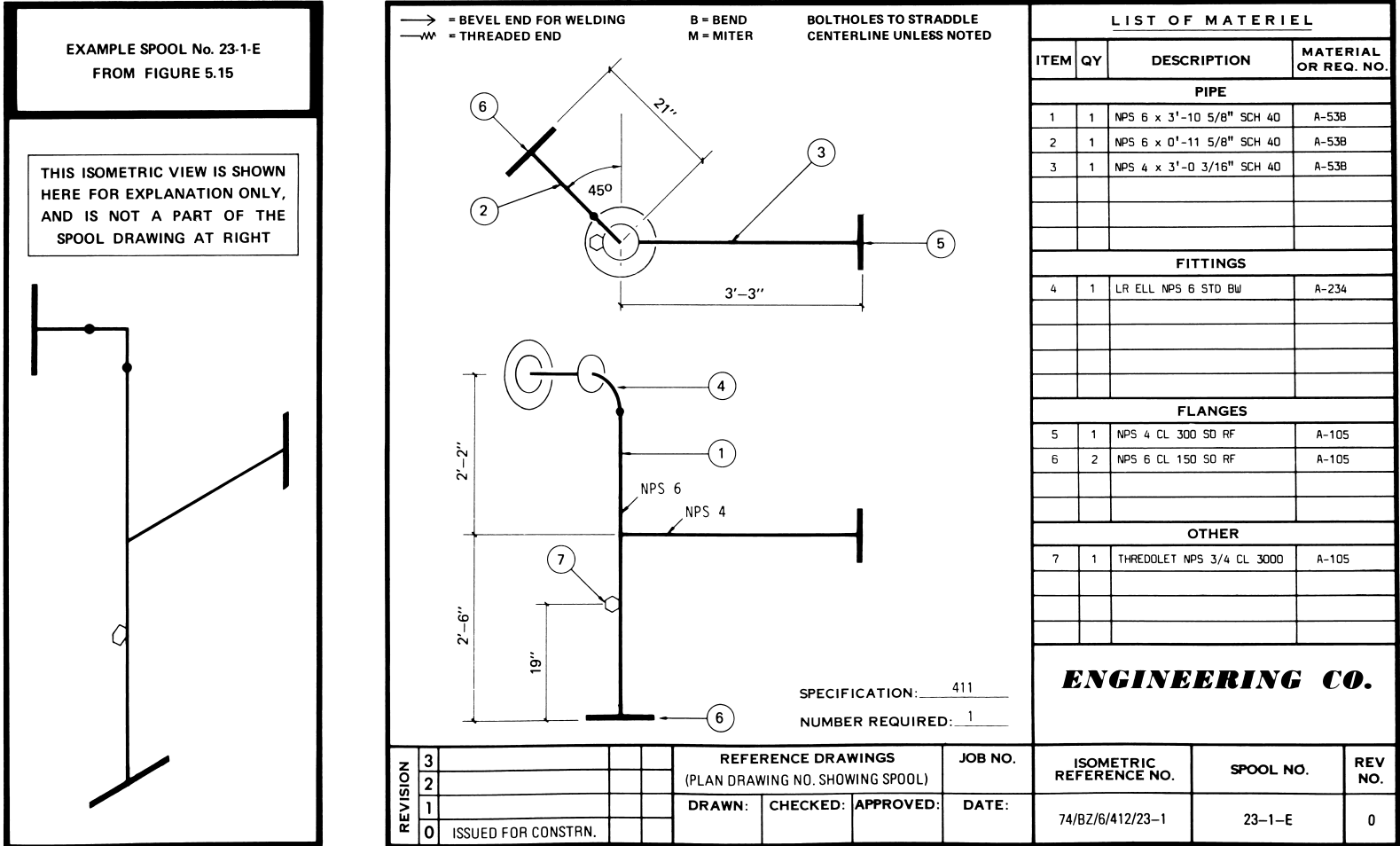
DIMENSIONING SPOOLS (WELDED ASSEMBLIES)

5.3.5

Allowance for weld spacing (root gap) is a shop set-up problem and should not be considered in making assembly drawings or detailed sketches. The Pipe Fabrication Institute recommends that an overall dimension is shown which is the sum of the nominal dimensions of the component parts.

A spool sheet deals with only one design of spool, and shows complete dimensional detail, lists material for making the spool, and specifies how many spools of that type are required. Figure 5.17 shows how a spool from figure 5.15 would be dimensioned.

FIGURE 5.17



## CHECKING & ISSUING DRAWINGS

5.4

### RESPONSIBILITIES

5.4.1

P&ID's, process flow diagrams and line designation sheets are checked by engineers in the project group.

Except for spool drawings, all piping drawings are checked by the piping group.

Orthographic spool drawings produced by the piping fabricator are not usually checked by the piping group, except for 'critical' spools, such as spools for overseas shipment and intricate spools.

Usually an experienced designer within the piping group is given the task of checking. Some companies employ persons specifically as design checkers.

The checker's responsibilities are set out in 4.1.2.

### CHECKING PIPING DRAWINGS

5.4.2

Prints of drawings are checked and corrected by marking with colored pencils. Areas to be corrected on the drawing are usually marked in red on the print. Correct areas and dimensions are usually marked in yellow.

Checked drawings to be changed should be returned to their originator whenever possible, for amendment. A new print is supplied to the checker with the original 'marked up' print for 'backchecking'.

### ISSUING DRAWINGS

5.4.3

Areas of a drawing awaiting further information or decision are ringed clearly on the reverse side and labeled 'HOLD'—refer to chart 5.8. (A black, red, or yellow china marker is suitable for film with a slick finish on the reverse side.)

Changes or revisions are indicated on the fronts of the sheets by a small triangle in the area of the revision. The revision number is marked inside the triangle, noted above the title block (or in an allocated panel) with a description of the revision, required initials, and date. The revision number may be part of the drawing number, or it may follow the drawing number (preferred method—see figure 5.17). The drawing as first issued is numbered the 'zero' revision.

A drawing is issued in three stages. The first issue is 'FOR APPROVAL', by management or client. The second issue is 'FOR CONSTRUCTION BID', when vendors are invited to bid for equipment and work contracts. The third issue is 'FOR CONSTRUCTION' following awarding of all purchase orders and contracts. Drawings may be reissued at each stage if significant changes are made. Minor changes may be made after the third stage (by agreement on cost and extent of work) but major changes may involve all three stages of issue.

## CHECKING PIPING DRAWINGS (PLANS, ELEVATIONS, & ISOS)

5.4.4

Points to be checked on all piping drawings include the following:

- Title of drawing
- Number of issue, and revision number
- Orientation: North arrow against plot plan
- Inclusion of graphic scale (if drawing is to be photographically reduced)
- Equipment numbers and their appearance on piping drawings
- That correct identification appears on all lines in all views
- Line material specification changes
- Agreement with specifications and agreement with other drawings
- That the drawing includes reference number(s) and title(s) to any other relevant drawings
- That all dimensions are correct
- Agreement with certified vendors' drawings for dimensions, nozzle orientation, manholes and ladders
- That face-to-face dimensions and pressure ratings are shown for all non-standard flanged items
- Location and identification of instrument connections
- Provision of line vents, drains, traps, and tracing. Check that vents are at all high points and drains at all low points of lines for hydrostatic test. Driplegs should be indicated and detailed. Traps should be identified, and piping detailed
- The following items should be labeled in one view only: tees and ells rolled at 45 degrees (see example in 5.2.8), short-radius ell, reducing ell, eccentric reducer and eccentric swage (note on plan views whether 'top flat' or 'bottom flat'), concentric reducer, concentric swage, non-standard or companion flange, reducing tee, special items of unusual material, of pressure rating different from that of the system, etc. Refer to charts 5.3, 5.4 and 5.5 for symbol usage
- That insulation has been shown as required by the P&ID
- Pipe support locations with support numbers
- That all anchors, dummy legs and welded supports are shown
- That the stress group's requirements have been met
- That all field welds are shown
- Correctness of scale
- Coordinates of equipment against plot plan
- Piping arrangement against P&ID requirements
- Possible interferences
- Adequacy of clearances of piping from steelwork, doors, windows and braces, ductwork, equipment and major electric apparatus, including control consoles, cables from motor control centers (MCC's), and fire-fighting equipment. Check accessibility for operation and maintenance

- That floor and wall penetrations are shown correctly
- Accessibility for operation and maintenance, and that adequate man-holes, hatches, covers, dropout and handling areas, etc. have been provided
- Foundation drawings with vendors' equipment requirements
- List of materiel, if any. Listed items should be identified once, either on the plan or the elevation drawings
- That section letters agree with the section markings on the plan view
- That drawings include necessary matchline information
- Appearance of necessary continuation sheet number(s)
- That spool numbers appear correctly
- Presence of all required signatures



This further point should be checked on isos:

- Agreement with model

These further points should be checked on spool sheets :

- That materiel is completely listed and described
- That the required number of spools of identical type is noted

## INSTRUMENTATION (As shown on P&ID's)

5.5

This section briefly describes the purposes of instruments and explains how instrumentation may be read from P&ID's. Piping drawings will *also* show the connection (coupling, etc.) to line or vessel. However, piping drawings should show only instruments connected to (or located in) piping and vessels. The only purpose in adding instrumentation to a piping drawing is to identify the connection, orifice plate or equipment to be installed on or in the piping, and to correlate the piping drawing to the P&ID.

### INSTRUMENT FUNCTION ONLY IS SHOWN

5.5.1

Instrumentation is shown on process diagrams and piping drawings by symbols. The functions of instruments are shown, not the instruments. Only the primary connection to a vessel or line, or devices installed in a line (such as orifice plates and control valves) are indicated.

There is some uniformity, among the larger companies at least, in the way in which instrumentation is shown. There is a willingness to adopt the recommendations of the Instrument Society of America, but adherence is not always complete. The ISA standard is S5.1, titled 'Instrumentation symbols and identification'.

Compliance with the ISA scheme is to some extent international. This is beneficial when drawings go from one country to another, as there is then no difficulty in understanding the instrumentation.

## INSTRUMENT FUNCTIONS

5.5.2

Although instruments are used for many purposes, their basic functions are few in number:

- (1) *To sense* a 'condition' of the process material, most commonly its pressure, temperature, flow rate or level. These 'conditions' are termed process variables. The piece of equipment that does the sensing is termed a 'primary element', 'sensor', or 'detector'.
- (2) *To transmit* a measure of the process variable from a primary element.
- (3) *To indicate* a measure of a process variable to the plant operator, by showing the measured value by a dial and pointer, pen and paper roll or digital display. Another form of indicator is an alarm which gives audible or visual warning when a process variable such as temperature approaches an unsafe or undesired value.
- (4) *To record* the measure of a process variable. Most recorders are electrically-operated pen-and-paper-roll types which record either the instantaneous value or the average over a time period.
- (5) *To control* the process variable. An instrument initiating this function is termed a 'controller'. A controller sustains or changes the value of the process variable by actuating a 'final control element' (this element is usually a valve, in process piping).

Many instruments combine two or more of these five functions, and may also have mechanical parts integrated — the commonest example of this is the self-contained control valve (see 3.1.10, under 'Pressure regulator', and chart 3.1).

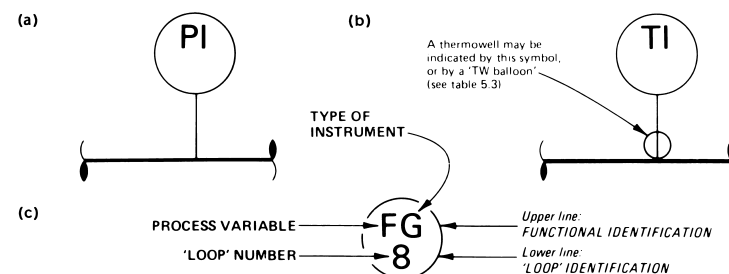
## HOW INSTRUMENTATION IS IDENTIFIED

5.5.3

The most-used instruments are pressure and temperature gages ('indicators') and are shown as in figure 5.18 (a) and (b). An example 'instrument identification number' (or 'tag number') is shown in figure 5.18 (c). The balloon around the number is usually drawn 7/16-inch diameter.

### INSTRUMENT IDENTIFICATION NUMBERS

FIGURE 5.18



In figure 5.18, 'P', 'T', and 'F' denote process variables pressure, temperature, and flow respectively. 'I' and 'G' show the type of instrument; indicator and gage respectively. Table 5.3 gives other letters denoting process variable, type of instrument, etc. The number '8', labeled 'loop number', is an example sequential number (allocated by an instrumentation engineer).

## INSTRUMENT MOUNTING, & MULTIPLE-FUNCTION INSTRUMENTS

5.5.4

A horizontal line in the ISA balloon shows that the instrument performing the function is to be 'board mounted' in a console, etc. Absence of this line shows 'local mounting', in or near the piping, vessel, etc.

### BOARD MOUNTING



### LOCAL MOUNTING



The ISA scheme shows instrument functions, not instruments. However, a multiple-function instrument can be indicated by drawing the balloons showing the separate functions so that the circles touch.

Sometimes, a multiple-function instrument will be indicated by a single balloon symbol, with a function identification, such as 'TRC' for a temperature recorder-controller. This practice is not preferred—it is better to draw (in this example) separate 'TR' and 'TC' balloons, touching.

## INTERCONNECTED INSTRUMENTS ('LOOPS')

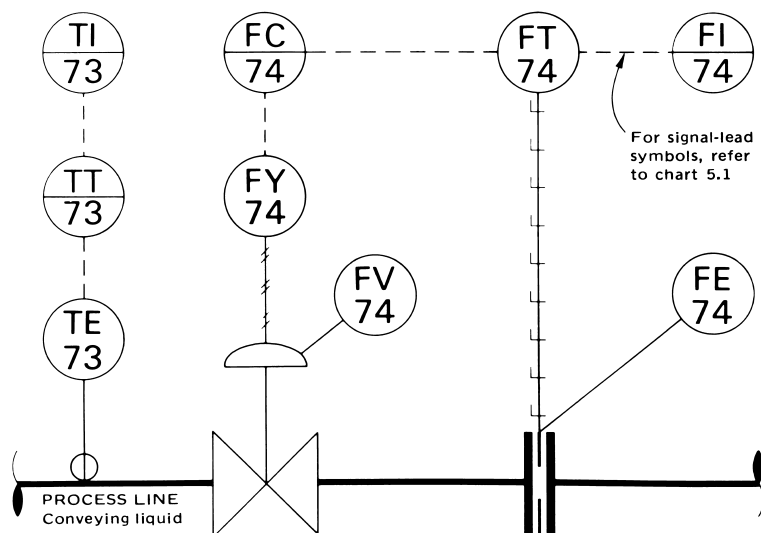
5.5.5

The ISA standard uses the term 'loop' to describe an interconnected group of instruments, which is not necessarily a closed-loop arrangement: that is, instrumentation used in a feedback (or feedforward) arrangement.

If several instruments are interconnected, they may be all allocated the same number for 'loop' identification. Figure 5.19 shows a process line served by one group of instruments (loop number 73) to sense, transmit and indicate temperature, and a second group (loop number 74) to sense, transmit, indicate, record and control flow rate.

### EXAMPLE INSTRUMENT 'LOOPS'

FIGURE 5.19



## SIGNAL LEADS

5.5.6

Elements, transmitters, recorders, indicators and controllers communicate with each other by means of signal leads — which are represented by lines on the drawing. The signal can be a voltage, the pressure of a fluid, etc.—these are the most common signals.

Symbols for instrument signal leads are given in chart 5.1.

## INSTRUMENTATION CODING : ISA CODING

TABLE 5.3

| PROCESS VARIABLE                |   | TYPE OF INSTRUMENT              |    |
|---------------------------------|---|---------------------------------|----|
| ANALYSIS .....                  | A | ALARM .....                     | A  |
| BURNER (Flame) .....            | B | USER'S CHOICE .....             | B  |
| COMBUSTION .....                | B | CONTROLLER .....                | C  |
| USER'S CHOICE .....             | C | CONTROL VALVE .....             | CV |
| USER'S CHOICE .....             | D | TRAP .....                      | CV |
| VOLTAGE .....                   | E | SENSOR (Primary Element) .....  | E  |
| FLOW RATE .....                 | F | RUPTURE DISC .....              | E  |
| USER'S CHOICE .....             | G | SIGHT or GAGE GLASS .....       | G  |
| CURRENT (Electric) .....        | I | TELEVISION MONITOR .....        | G  |
| POWER .....                     | J | INDICATOR .....                 | I  |
| TIME (Time Control/Clock) ..... | K | CONTROL STATION .....           | K  |
| LEVEL .....                     | L | LIGHT (Pilot/Operation) .....   | L  |
| USER'S CHOICE .....             | M | USER'S CHOICE .....             | N  |
| USER'S CHOICE .....             | N | FLOW RESTRICTION ORIFICE .....  | O  |
| USER'S CHOICE .....             | O | TEST POINT (Sample Point) ..... | P  |
| PRESSURE/VACUUM .....           | P | RECORDER .....                  | R  |
| RADIATION .....                 | R | SWITCH .....                    | S  |
| SPEED (or Frequency) .....      | S | TRANSMITTER .....               | T  |
| TEMPERATURE .....               | T | MULTIFUNCTION .....             | U  |
| MULTIVARIABLE .....             | U | VALVE/DAMPER .....              | V  |
| VIBRATION .....                 | V | WELL .....                      | W  |
| WEIGHT (or Force) .....         | W | UNCLASSIFIED .....              | X  |
| UNCLASSIFIED .....              | X | RELAY .....                     | Y  |
| EVENT (Response to) .....       | Y | DRIVER .....                    | Z  |
| POSITION, DIMENSION .....       | Z | ACTUATOR .....                  | Z  |

### QUALIFYING LETTER AFTER THE 'PROCESS VARIABLE' LETTER

DIFFERENTIAL . . . D

THE QUALIFYING LETTER IS USED:—

When the difference between two values of the process variable is involved

TOTAL . . . . . Q

When the process variable is to be summed over a period of time. For example, flow rate can be summed to give total volume

RATIO . . . . . F

When the ratio of two values of the process variable is involved

SAFETY ITEM . . . S

To denote an item such as a relief valve or rupture disc

'HAND' . . . . . H

To denote a hand-operated or hand-started item

### QUALIFYING LETTER AFTER THE 'TYPE OF INSTRUMENT' LETTER

HIGH . . . . . H

To denote instrument action on 'high' set value of the process variable

INTERMEDIATE. . . M

To denote instrument action on 'intermediate' set value of the process variable

LOW . . . . . L

To denote instrument action on 'low' set value of the process variable

## LISTING PIPING MATERIEL ON DRAWINGS

### 5.6

In the engineering construction industry, it is usual for piping components to be given a code number which appears in the piping specification. In companies not primarily engaged in plant construction, materiel is frequently listed on drawings.

### DIFFERENT FORMS OF LIST

#### 5.6.1

This list is usually titled 'list of material', or preferably, 'list of materiel', as items of hardware are referred to. 'Parts list' and 'Bill of materiel' are alternate headings.

Either a separate list can be made for materiel on several drawings, or each drawing sheet can include a list for items on the particular drawing. Lists on drawings are written in the space above the title block. Column headings normally used for the list are:

| LIST OF MATERIEL |          |             |   |
|------------------|----------|-------------|---|
| ITEM NUMBER      | QUANTITY | DESCRIPTION | REMARK, REQUISITION NUMBER, OR COMPANY CODE |

### SUGGESTED LISTING SCHEME

#### 5.6.2

Vessels, pumps, machinery and instruments are normally listed separately from piping hardware. However, it is not uncommon, on small projects or revamp work, to list all materiel on a drawing.

### CLASSIFICATION FOR PIPING COMPONENTS

#### CHART 5.11

| CLASS | INTENDED DUTY OF HARDWARE WITH RESPECT TO FLUID  |                 | EXAMPLE HARDWARE  |
|-------|--|-----------------|---|
| I     | CONVEYANCE: <i>To provide a path for fluid flow</i>  |                 | Pipe, fittings, ordinary flanges, bolt and gasket sets  |
| II    | FLOW CONTROL: <i>To produce a large change in flow rate or pressure of fluid</i>   | (A) Non-powered | In-line valve, orifice plate, venturi   |
|       |  | (B) Powered     | Pump, ejector   |
| III   | SEPARATION: <i>To remove material by mechanical means from the fluid</i>   |                 | Steam trap, discharge valve, safety or relief valve, screen, strainer   |
| IV    | HEATING OR COOLING: <i>To change the temperature of the fluid by adding or removing heat</i>   |                 | Jacketed pipe, tracer   |
| V     | MEASUREMENT: <i>To measure a variable of the fluid, such as flow rate, temperature, pressure, density, viscosity, turbidity, color</i> |                 | Gages (all types), thermometers (all types), flow meter, densitometer, sensor housing (such as a thermowell) and other special fittings for instruments |
| VI    | NONE: <i>Ancillary hardware</i>  |                 | Insulation, reinforcement, hanger, support  |

Haphazard listing of items makes reference troublesome. The scheme suggested in chart 5.11 is based on the duty of the hardware and can be extended to listing equipment if desired. Items of higher pressure rating and larger size can be listed first within each class.

### LISTING SPECIFIC ITEMS

#### 5.6.3

Under the heading DESCRIPTION, often on drawings the size of the item is stated first. A typical order is: SIZE (NPS), RATING (class, schedule number, etc.), NAME (of item), MATERIAL (ASTM or other material specification), and FEATURE (design feature).

Descriptions are best headed by the NAME of the item, followed by the SIZE, RATING, FEATURE(S), and MATERIAL. As material listings are commonly handled by data-processing equipment, beginning the description of an item by name is of assistance in handling the data. The description for 'pipe' is detailed.

### EXAMPLE LISTING FOR PIPE

- NAME: State 'PIPE'
- SIZE: Specify nominal pipe size. See 2.1.3 and tables P-1
- RATING: Specify wall thickness as either a schedule number, a manufacturers' weight, etc. See tables P-1. SCH=schedule, STD= standard, XS= extra-strong, XXS= double-extra-strong, API= American Petroleum Institute.
- FEATURE: Specify design feature(s) unless covered by a pipe specification for the project.  
  
Pipe is available seamless or with a welded seam—examples of designations are: SMLS = seamless, FBW = furnace-butt-welded, ERW = electric-resistance-welded GALV = galvanized. Specify ends: T&C = threaded and coupled, BE = beveled end, PE = plain end.
- MATERIAL: Carbon-steel pipe is often ordered to ASTM A53 or A106, Grade A or B. Other specifications are given in tables 7.5 and 2.1.

### POINTS TO CHECK WHEN MAKING THE LIST

#### 5.6.4

- See that all items in the list have been given a sequential item number
- Label the items appearing on the piping drawings with the item number from the list. Write the item number in a circle with a fine line or arrow pointing to the item on the drawing. Each item in the list of materiel is indicated in this way once on the plan or elevational piping drawings
- Verify that all data on the list agree with:
  - Requirements set out in piping drawings
  - Available hardware in the manufacturers' catalogs

# DESIGN OF PIPING SYSTEMS:

## Including Arrangement, Supporting, Insulation, Heating, Venting and Draining of Piping, Vessels and Equipment

### ARRANGING PIPING

6.1

#### GUIDELINES & NOTES

6.1.1

*Simple arrangements and short lines minimize pressure drops and lower pumping costs.*

Designing piping so that the arrangement is 'flexible' reduces stresses due to mechanical or thermal movement—refer to figure 6.1 and 'Stresses on piping', this section.

Inside buildings, piping is usually arranged parallel to building steelwork to simplify supporting and improve appearance.

Outside buildings, piping can be arranged: (1) On piperacks. (2) Near grade on sleepers. (3) In trenches. (4) Vertically against steelwork or large items of equipment.

#### PIPING ARRANGEMENT

- Use standard available items wherever possible
- Do not use miters unless directed to do so
- Do not run piping under foundations. (Pipes may be run under grade beams)
- Piping may have to go thru concrete floors or walls. Establish these points of penetration as early as possible and inform the group concerned (architectural or civil) to avoid cutting existing reinforcing bars
- Preferably lay piping such as lines to outside storage, loading and receiving facilities, at grade on pipe sleepers (see figure 6.3) if there is no possibility of future roads or site development

- Avoid burying steam lines that pocket, due to the difficulty of collecting condensate. Steam lines may be run below grade in trenches provided with covers or (for short runs) in sleeves
- Lines that are usually buried include drains and lines bringing in water or gas. Where long cold winters freeze the soil, burying lines below the frost line may avoid the freezing of water and solutions, saving the expense of tracing long horizontal parts of the lines
- Include removable flanged spools to aid maintenance, especially at pumps, turbines, and other equipment that will have to be removed for overhaul
- Take gas and vapor branch lines from tops of headers where it is necessary to reduce the chance of drawing off condensate (if present) or sediment which may damage rotating equipment
- Avoid pocketing lines—arrange piping so that lines drain back into equipment or into lines that can be drained
- Vent all high points and drain all low points on lines — see figure 6.47. Indicate vents and drains using symbols in chart 5.7. Carefully-placed drains and valved vents permit lines to be easily drained or purged during shutdown periods: this is especially important in freezing climates and can reduce winterizing costs

#### ARRANGE FOR SUPPORTING

- Group lines in pipeways, where practicable
- Support piping from overhead, in preference to underneath
- Run piping beneath platforms, rather than over them

#### REMOVING EQUIPMENT & CLEANING LINES

- Provide union- and flanged joints as necessary, and in addition use crosses instead of elbows, to permit removing material that may solidify

## CLEARANCES & ACCESS

- Route piping to obtain adequate clearance for maintaining and removing equipment
- Locate within reach, or make accessible, all equipment subject to periodic operation or inspection — with special reference to check valves, pressure relief valves, traps, strainers and instruments
- Take care to not obstruct access ways — doorways, escape panels, truckways, walkways, lifting wells, etc.
- Position equipment with adequate clearance for operation and maintenance. Clearances often adopted are given in table 6.1. In some circumstances, these clearances may be inadequate—for example, with shell-and-tube heat exchangers, space must be provided to permit withdrawal of the tubes from the shell

| CLEARANCES & DIMENSIONS              |   | TABLE 6.1 |
|--------------------------------------|---|-----------|
| <b>MINIMUM CLEARANCES</b>            |   |           |
| <b>HORIZONTAL CLEARANCES:</b>        | Operating space around equipment †                                | 2ft 6in.  |
|                                      | Centerline of railroad to nearest obstruction: (1) Straight track | 8ft 6in.  |
|                                      | (2) Curved track  | 9ft 6in.  |
|                                      | Manhole to railing or obstruction                                 | 3ft 0in.  |
| <b>VERTICAL CLEARANCES:</b>          | Over walkway, platform, or operating area                         | 6ft 6in.  |
|                                      | Over stairway   | 7ft 0in.  |
|                                      | Over high point of plant roadway:                                 |           |
|                                      | (1) Minor roadway   | 17ft 0in. |
|                                      | (2) Major roadway   | 20ft 0in. |
|                                      | Over railroad from top of rail                                    | 22ft 6in. |
| <b>MINIMUM HORIZONTAL DIMENSIONS</b> |   |           |
|                                      | Width of walkway at floor level                                   | 3ft 0in.  |
|                                      | Width of elevated walkway or stairway                             | 2ft 6in.  |
|                                      | Width of rung of fixed ladder See chart P-2.                      | 16in.     |
|                                      | Width of way for forklift truck                                   | 8ft 0in.  |
| <b>VERTICAL DIMENSIONS</b>           |   |           |
|                                      | Railing. Top of floor, platform, or stair, to: (1) Lower rail     | 1ft 9in.  |
|                                      | (2) Upper rail  | 3ft 6in.  |
|                                      | Manhole centerline to floor                                       | 3ft 0in.  |
|                                      | Valves: See table 6.2 and chart P-2.                              |           |

†Equipment such as heat exchangers, compressors and turbines will require additional clearance. Check manufacturers' drawings to determine particular space requirements. Refer to figure 6.33 and table 6.5 for spacing heat exchangers.

- Ensure very hot lines are not run adjacent to lines carrying temperature sensitive fluids, or elsewhere, where heat might be undesirable
- Establish sufficient headroom for ductwork, essential electrical runs, and at least two elevations for pipe run north-south and east-west (based on clearance of largest lines, steelwork, ductwork, etc.—see figure 6.49)
- Elevations of lines are usually changed when changing horizontal direction where lines are grouped together or are in a congested area, so as not to block space where future lines may have to be routed

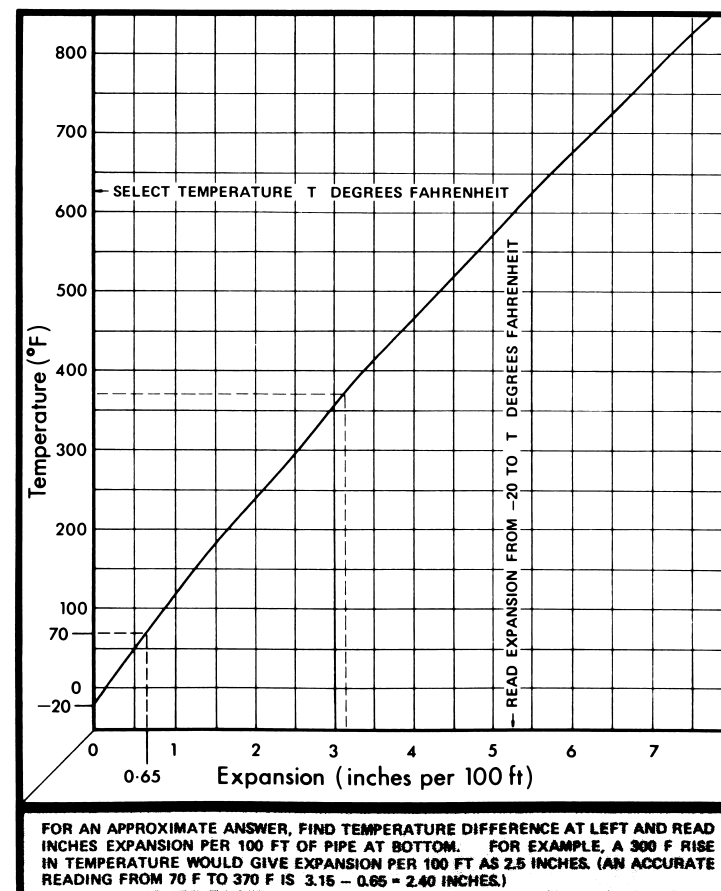
- Stagger flanges, with 12-inch minimum clearance from supporting steel
- Keep field welds and other joints at least 3 inches from supporting steel, building siding or other obstruction. Allow room for the joint to be made
- Allow room for loops and other pipe arrangements to cope with expansion by early consultation with staff concerned with pipe stressing. Notify the structural group of any additional steel required to support such loops

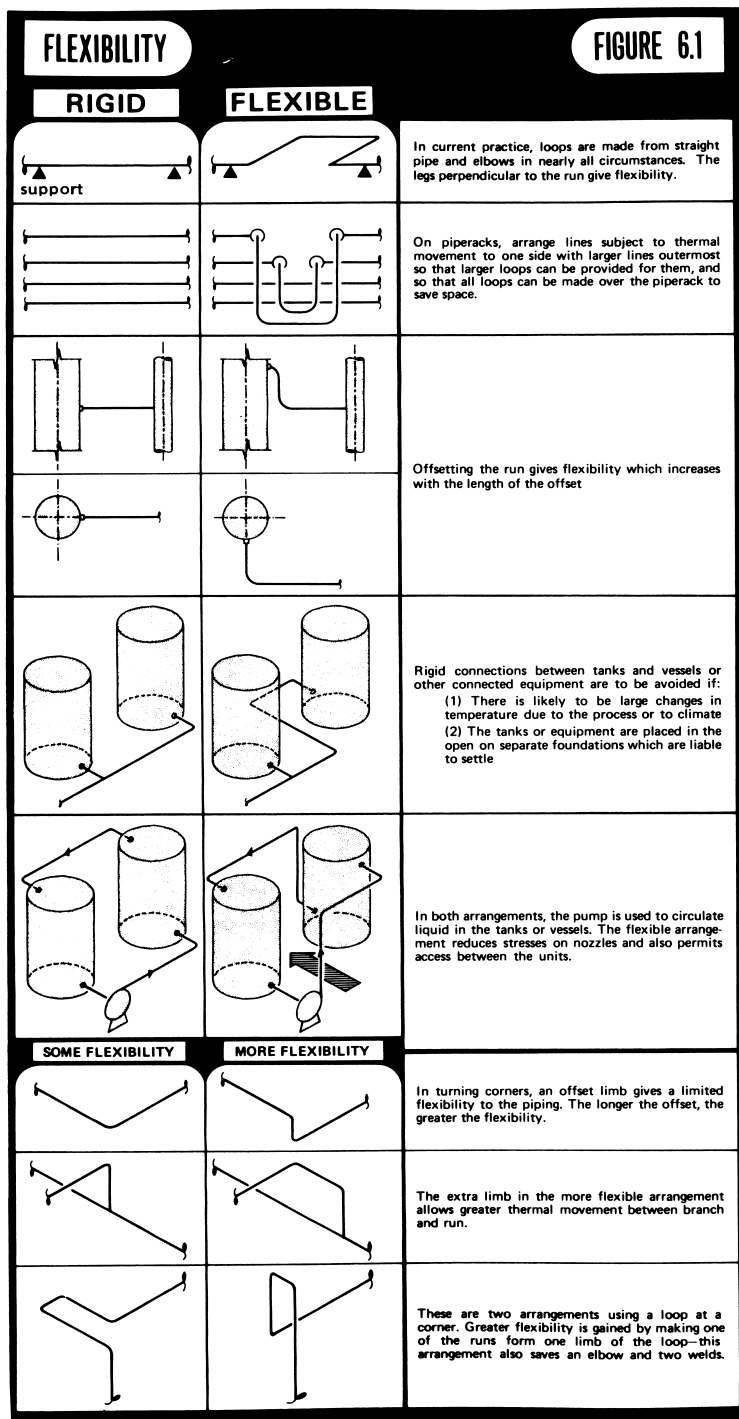
## THERMAL MOVEMENT

Maximum and minimum lengths of a pipe run will correspond to the temperature extremes to which it is subjected. The amount of expansion or shrinkage in steel per degree change in temperature ('coefficient of expansion') is approximately the same — that is, the expansion from 40F to 41F is about the same as from 132 F to 133 F, or from 179 F to 180 F, etc. Chart 6.1 gives changes in line length for changes in temperature.

EXPANSION OF CARBON-STEEL PIPE

CHART 6.1





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## STRESSES ON PIPING

**THERMAL STRESSES** Changes in temperature of piping, due either to change in temperature of the environment or of the conveyed fluid, cause changes in length of the piping. This expansion or contraction in turn causes strains in piping, supports and attached equipment.

**SETTLEMENT STRAINS** Foundations of large tanks and heavy equipment may settle or tilt slightly in the course of time. Connected piping and equipment not on a common foundation will be stressed by the displacement unless the piping is arranged in a configuration flexible enough to accommodate multiple-plane movement. This problem should not arise in new construction but could occur in a modification to a plant unit or process.

## FLEXIBILITY IN PIPING

To reduce strains in piping caused by substantial thermal movement, flexible and expansion joints may be used. However, the use of these joints may be minimized by arranging piping in a flexible manner, as illustrated in figure 6.1. Pipe can flex in a direction perpendicular to its length: thus, the longer an offset, or the deeper a loop, the more flexibility is gained.

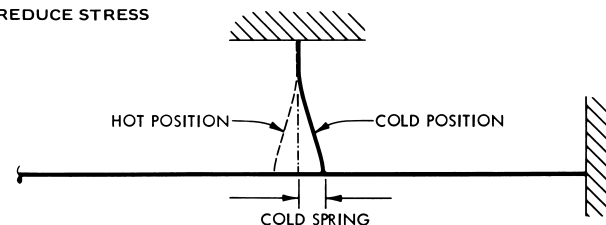
## COLD SPRING

Cold springing of lines should be avoided if an alternate method can be used. A line may be cold sprung to reduce the amplitude of movement from thermal expansion or contraction in order: (a) To reduce stress on connections. (b) To avoid an interference.

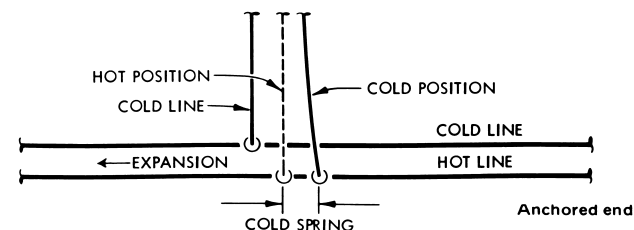
Figure 6.2 schematically illustrates the use of cold springing for both purposes. Cold springing in example (a) consists of making the branch in the indicated cold position, which divides thermal movement between the cold and hot positions. In example (b) the cold spring is made equal to the thermal movement.

FIGURE 6.2

### (a) TO REDUCE STRESS



### (b) TO AVOID AN INTERFERENCE



In the following example, cold springing is employed solely to reduce a stress:

A long pipe connected by a 90-degree elbow and flange to a nozzle may on heating expand so that it imposes a load on the nozzle in excess of that recommended. Assume that piping to the nozzle has been installed at ambient temperature, and that the pipe expands 0.75 inch when hot material flows thru it, putting a lateral (sideways) load of 600 lb on the nozzle.

If the pipe had 0.375 inch of its length removed before connection, the room-temperature lateral load on the nozzle would be about 300 lb (instead of zero), and the hot load would be reduced to about 300 lb.

The fraction of the expansion taken up can be varied. A cold spring of 50% of the expansion between the temperature extremes gives the most benefit in reducing stress. Cold springing is not recommended if an alternate solution can be used. Refer to the Code for Pressure Piping ANSI B31 and to table 7.2.

### RESISTANCE OF PIPING TO FLOW

All piping has resistance to flow. The smaller the flow cross section and the more abrupt the change in direction of flow, the greater is the resistance and loss of pressure. For a particular line size the resistance is proportional to the length of pipe, and the resistance of fittings, valves, etc. may be expressed as a length of pipe having the same resistance to flow. Table F-10 gives such equivalent lengths of pipe for fittings, valves, etc.

Table F-11 gives pressure drops for water flowing thru SCH 40 pipe at various rates. Charts to determine the economic size (NPS) of piping are given in the Chemical Engineer's Handbook and other sources.

### SLIDERULE FOR FLOW PROBLEMS

Problems of resistance to flow can be quickly solved with the aid of the slide-rule calculator obtainable from Tube Turns Division of Chemetron Corporation, PO Box 32160, Louisville, KY 40232.

### PIPERACKS

#### 6.1.2

A 'pipeway' is the space allocated for routing several parallel adjacent lines. A 'piperack' is a structure in the pipeway for carrying pipes and is usually fabricated from steel, or concrete and steel, consisting of connected □-shaped frames termed 'bents' on top of which the pipes rest. The vertical members of the bents are termed 'stanchions'. Figure 6.3 shows two piperacks using this form of construction, one of which is 'double-decked'. Piperacks for only two or three pipes are made from 'T'-shaped members, termed 'tee-head supports'.

Piperacks are expensive, but are necessary for arranging the main process and service lines around the plant site. They are made use of in secondary ways, principally to provide a protected location for ancillary equipment.

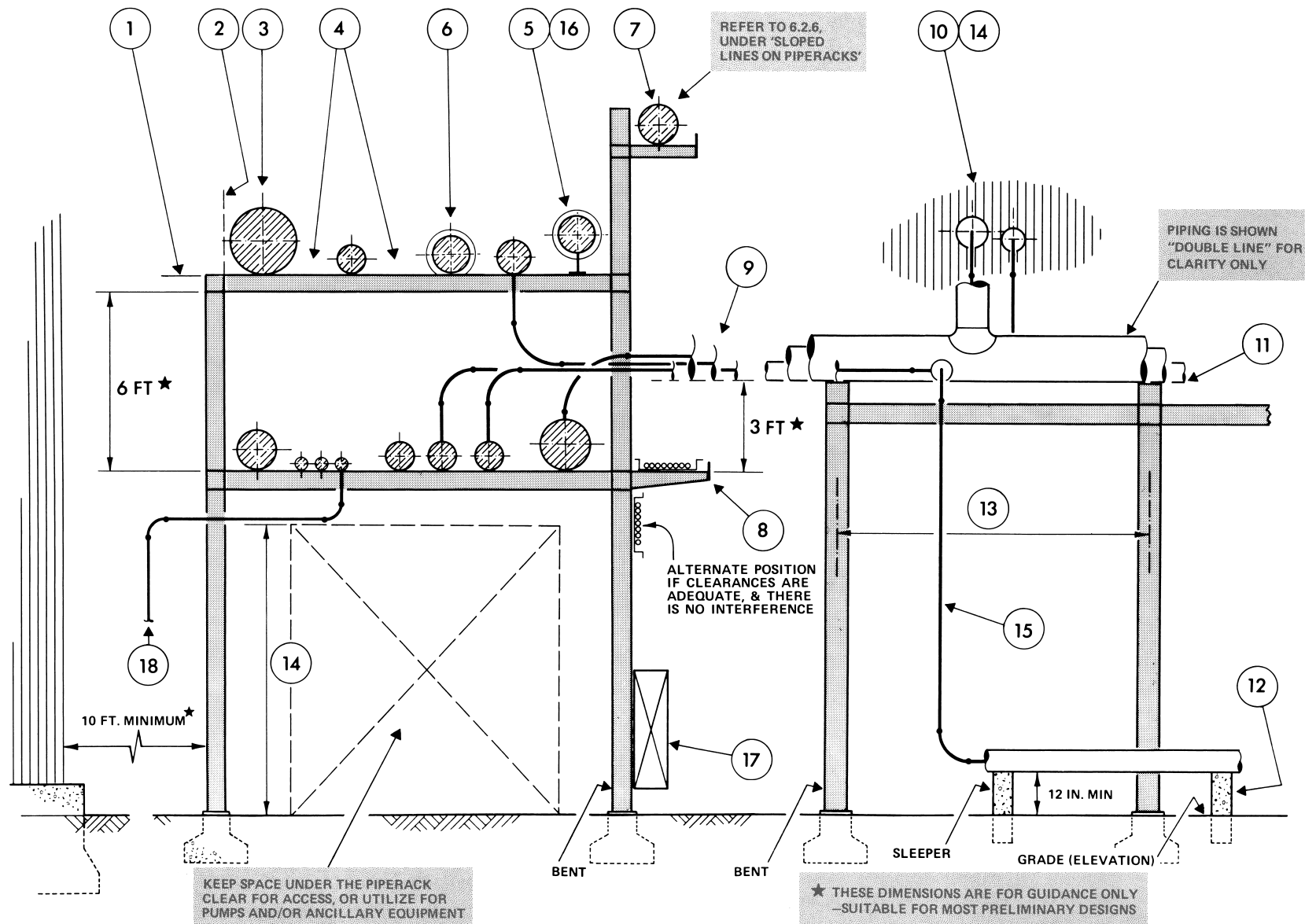
Pumps, utility stations, manifolds, fire-fighting and first-aid stations can be located under the piperack. Lighting and other fixtures can be fitted to stanchions. Air-cooled heat exchangers can be supported above the piperack.

The smallest size of pipe run on a piperack without additional support is usually 2 inch. It may be more economic to change proposed small lines to 2-inch pipe, or to suspend them from 4-inch or larger lines, instead of providing additional support.

Table S-1 and charts S-2 give stress and support data for spans of horizontal pipe.

## KEY FOR FIGURE 6.3

- (1) WHEN USING A DOUBLE DECK, IT IS CONVENTIONAL TO PLACE UTILITY AND SERVICE PIPING ON THE UPPER LEVEL OF THE PIPERACK
- (2) DO NOT RUN PIPING OVER STANCHIONS AS THIS WILL PREVENT ADDING ANOTHER DECK
- (3) PLACE LARGE LIQUID-FILLED PIPES NEAR STANCHIONS TO REDUCE STRESS ON HORIZONTAL MEMBERS OF BENTS. HEAVY LIQUID-FILLED PIPES (12-in AND LARGER) ARE MORE ECONOMICALLY RUN AT GRADE—SEE NOTE (12)
- (4) PROVIDE DISTRIBUTED SPACE FOR FUTURE PIPES—APPROXIMATELY AN ADDITIONAL 25 PERCENT (THAT IS, 20 PERCENT OF FINAL WIDTH—SEE TABLES A-1)
- (5) HOT PIPES ARE USUALLY INSULATED AND MOUNTED ON SHOES
- (6) WARM PIPES MAY HAVE INSULATION LOCALLY REMOVED AT SUPPORTS
- (7) THE HEIGHT OF A RELIEF HEADER IS FIXED BY ITS POINT OF ORIGIN AND THE SLOPE REQUIRED TO DRAIN THE LINE TO A TANK, Etc.
- (8) ELECTRICAL AND INSTRUMENT TRAYS (FOR CONDUIT AND CABLES) ARE BEST PLACED ON OUTRIGGERS OR BRACKETS AS SHOWN, TO PRESENT THE LEAST PROBLEM WITH PIPES LEAVING THE PIPEWAY. ALTERNATELY, TRAYS MAY BE ATTACHED TO THE STANCHIONS
- (9) WHEN CHANGE IN DIRECTION OF A HORIZONTAL LINE IS MADE, IT IS BEST ALSO TO MAKE A CHANGE OF ELEVATION (EITHER UP OR DOWN). THIS AVOIDS BLOCKING SPACE FOR FUTURE LINES. 90-DEGREE CHANGES IN DIRECTION OF THE WHOLE PIPEWAY OFFER THE OPPORTUNITY TO CHANGE THE ORDER OF LINES. A SINGLE DECK IS SHOWN AT AN INTER-MEDIATE ELEVATION
- (10) SOMETIMES INTERFACES ARE ESTABLISHED TO DEFINE BREAKPOINTS FOR CONTRACTED WORK (WHERE ONE CONTRACTOR'S PIPING HAS TO JOIN WITH ANOTHERS). AN INTERFACE IS AN IMAGINARY PLANE WHICH MAY BE ESTABLISHED FAR ENOUGH FROM A WALL, SIDING, PROCESS UNIT, OR STORAGE UNIT TO ENABLE CONNECTIONS TO BE MADE
- (11) PIPES SHOULD BE RACKED ON A SINGLE DECK IF SPACE PERMITS
- (12) PIPING SHOULD BE SUPPORTED ON SLEEPERS AT GRADE IF ROADS, WALKWAYS, Etc., WILL NOT BE REQUIRED OVER THE PIPEWAY AT A LATER DATE. PIPING 'AT GRADE' SHOULD BE 12 INCHES OR MORE ABOVE GRADE
- (13) CURRENT PRACTICE IS TO SPACE BENTS 20–25 FEET APART. THIS SPACING IS A COMPROMISE BETWEEN THE ACCEPTABLE DEFLECTIONS OF THE SMALLER PIPES AND THE MOST ECONOMIC BEAM SECTION DESIRED FOR THE PIPERACK. PIPERACKS ARE USUALLY NOT OVER 25 FEET IN WIDTH. IF MORE ROOM IS NEEDED, THE PIPERACK IS DOUBLE- OR TRIPLE-DECKED
- (14) MINIMUM CLEARANCE UNDERNEATH THE PIPERACK IS DETERMINED BY AVAILABLE MOBILE LIFTING EQUIPMENT REQUIRING ACCESS UNDER THE PIPERACK. VERTICAL CLEARANCES SHOULD BE AS SET OUT IN TABLE 6.1 BUT CANNOT NECESSARILY BE ADHERED TO AS ELEVATIONS OF PIPES AT INTERFACES ARE SOMETIMES FIXED BY PLANT SUBCONTRACTORS. IF THIS SITUATION ARISES, THE PIPING GROUP SHOULD ESTABLISH MAXIMUM AND MINIMUM ELEVATIONS WHICH THE PIPING SUBCONTRACTORS MUST WORK TO—THIS HELPS TO AVOID PROBLEMS AT A LATER DATE. CHECK THE MINIMUM HEIGHT REQUIRED FOR ACCESS WHERE THE PIPERACK RUNS PAST A UNIT OR PLANT ENTRANCE
- (15) WHEN SETTING ELEVATIONS FOR THE PIPERACK, TRY TO AVOID POCKETS IN THE PIPING. LINES SHOULD BE ABLE TO DRAIN INTO EQUIPMENT OR LINES THAT CAN BE DRAINED
- (16) GROUP HOT LINES REQUIRING EXPANSION LOOPS AT ONE SIDE OF THE PIPERACK FOR EASE OF SUPPORT—SEE FIGURE 6.1
- (17) LOCATE UTILITY STATIONS, CONTROL (VALVE) STATIONS, AND FIREHOSE POINTS ADJACENT TO STANCHIONS FOR SUPPORTING
- (18) LEAVE SPACE FOR DOWNCOMERS TO PUMPS, Etc., BETWEEN PIPERACK AND ADJACENT BUILDING OR STRUCTURE



## VALVES IN PIPING DESIGN

### 6.1.3

Valves are used for these purposes:

- (1) Process control during operation
- (2) Controlling services and utilities—steam, water, air, gas and oil
- (3) Isolating equipment or instruments, for maintenance
- (4) Discharging gas, vapor or liquid
- (5) Draining piping and equipment on shutdown
- (6) Emergency shutdown in the event of plant mishap or fire

### WHICH SIZE VALVE TO USE ?

Nearly all valves will be line size — one exception is control valves, which are usually one or two sizes smaller than line size; never larger.

At control stations and pumps it has been almost traditional to use line-size isolating valves. However, some companies are now using isolating valves at control stations the same size as the control valve, and at pumps are using 'pump size' isolating valves at suction and discharge. The choice is usually an economic one made by a project engineer.

The sizes of bypass valves for control stations are given in 6.1.4, under 'Control (valve) stations'.

### WHERE TO PLACE VALVES

See 6.3.1 for valving pumps, under 'Pump emplacement & connections'.

- Preferably, place valves in lines from headers (on piperacks) in horizontal rather than vertical runs, so that lines can drain when the valves are closed. (In cold climates, water held in lines may freeze and rupture the piping: such lines should be traced — see 6.8.2)
- To avoid spooling unnecessary lengths of pipe, mount valves directly onto flanged equipment, if the flange is correctly pressure-rated. See 6.5.1 under 'Nozzle loading'
- A relief valve that discharges into a header should be placed higher than the header in order to drain into it
- Locate heavy valves near suitable support points. Flanges should be not closer than 12 inches to the nearest support, so that installation is not hampered
- For appearance, if practicable, keep centerlines of valves at the same height above floor, and in-line on plan view

### OPERATING ACCESS TO VALVES

- Consider frequency of operation when locating manually-operated valves
- Locate frequently-operated valves so they are accessible to an operator from grade or platform. Above this height and up to 20 ft, use chain operators or extension stem. Over 20 ft, consider a platform or remote operation

## VALVE OPERATING HEIGHTS \*

TABLE 6.2

| ORDER OF PREFERENCE FOR VALVE LOCATION  | STEM CENTERLINE ELEVATION FOR HORIZONTAL VALVES |                | HANDWHEEL ELEVATION FOR VERTICAL VALVES<br>(upright, closed) | MINIMUM ELEVATION OF HANDWHEEL RIM FOR TILTED VALVES (handwheel overhead) |                   |
|---|---|----------------|--|---|-------------------|
|   | OPERATING                                       | MAINTENANCE    |  | ANGLE OF STEM FROM VERTICAL   | MINIMUM ELEVATION |
| 1st   | 3'-6" to 4'-6"                                  | 3'-6" to 4'-6" | 3'-9" to 4'-3"   |   |                   |
| 2nd †   | 2'-0" to 3'-6"                                  | 1'-0" to 3'-6" | 2'-0" to 3'-9"   |   |                   |
| 3rd †<br>(HEAD HAZARD)  | 4'-6" to 6'-6"+<br>½ handwheel diameter         | 4'-6" to 7'-9" |  | 30°   | 5'-0"             |
|   |   |                |  | 45°   | 5'-6"             |
|   |   |                |  | 60°   | 6'-0"             |
| ACCEPTABLE FOR 1-INCH AND SMALLER VALVES  | 0'-6" to 2'-0"<br>and<br>6'-9" to 7'-6"         |                |  |   |                   |
| * REFER TO CHART P-2 IN PART II<br>† TO MINIMIZE HAZARD TO PERSONNEL IF VALVES ARE TO BE LOCATED AT HEIGHTS WITHIN 2nd AND 3rd CHOICES, AVOID POINTING STEMS INTO WALKWAYS AND WORKING AREAS. TRY TO PLACE VALVES CLOSE TO WALLS OR LARGE ITEMS WHICH ARE CLEARLY SEEN. |   |                |  |   |                   |

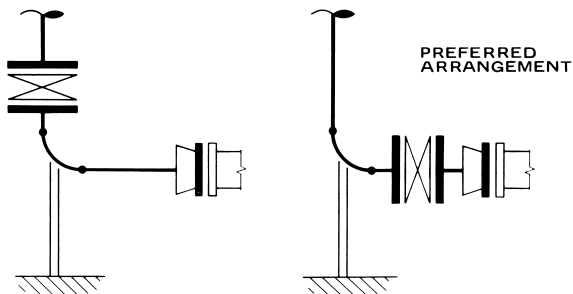
- Infrequently-used valves can be reached by a ladder—but consider alternatives
- Do not locate valves on piperacks, unless unavoidable
- Group valves which would be out of reach so that all can be operated by providing a platform, if automatic operators are not used
- If a chain is used on a horizontally-mounted valve, take the bottom of the loop to within 3 ft of floor level for safety, and provide a hook nearby to hold the chain out of the way —see 3.1.2, under 'Chain'
- Do not use chain operators on screwed valves, or on any valve 1½-inches and smaller
- With lines handling dangerous materials it is better to place valves at a suitably low level above grade, floor, platform, etc., so that the operator does not have to reach above head height

### ACCESS TO VALVES IN HAZARDOUS AREAS

- Locate main isolating valves where they can be reached in an emergency such as an outbreak of fire or a plant mishap. Make sure that personnel will be able to reach valves easily by walkway or automobile
- Locate manually-operated valves at the plant perimeter, or outside the hazardous area
- Ensure that automatic operators and their control lines will be protected from the effects of fire
- Make use of brick or concrete walls as possible fire shields for valve stations
- Inside a plant, place isolating valves in accessible positions to shut feed lines for equipment and processes having a fire risk
- Consider the use of automatic valves in fire-fighting systems to release water, foam and other fire-fighting agents, responding to heat-fusible links, smoke detectors, etc., triggered by fire or undue rise in temperature —advice may be obtained from the insurer and the local fire department

## MAKE MAINTENANCE SIMPLE

- Provide access for mobile lifting equipment to handle heavy valves
- Consider providing lifting davits for heavy valves difficult to move by other means, if access is restricted
- If possible, arrange valves so that supports will not be on removable spools:



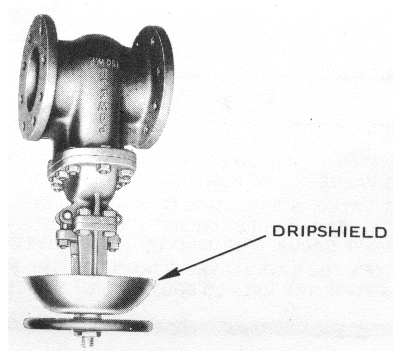
- A plug valve requiring lubrication must be easily accessible, even though it may not be frequently operated

## MAKE MAINTENANCE SAFE

- Use line-blind valves, spectacle plates or the 'double block and bleed' where positive shutoff is required either for maintenance or process needs – see 2.7

## ORIENTATION OF VALVE STEMS

- Do not point valve stems into walkways, truckways, ladder space, etc.
- Unless necessary, do not arrange gate and globe valves with their stems pointing downward (at *any* angle below the horizontal), as:–
  - (1) Sediment may collect in the gland packing and score the stem.
  - (2) A projecting stem may be a hazard to personnel.
- If an inverted position is necessary, consider employing a dripshield:



## CLOSING DOWN LINES

Consider valve-closing time in shutting down or throttling large lines. Rapid closure of the valve requires rapid dissipation of the liquid's kinetic energy, with a risk of rupturing the line. Long-distance pipelines present an example of this problem.

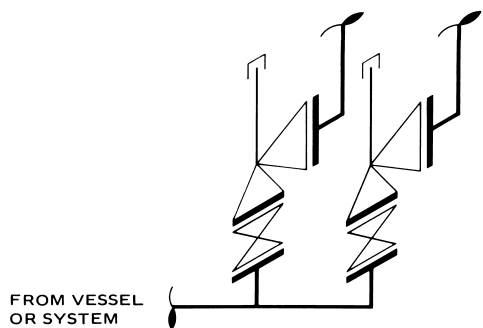
A liquid line fitted with a fast-closing valve should be provided with a standpipe upstream and close to the valve to absorb the kinetic energy of the liquid. A standpipe is a closed vertical branch on a line: air or other gas is trapped in this branch to form a pneumatic cushion.

## IF THERE IS NO P&ID .....

- Provide valves at headers, pumps, equipment, etc., to ensure that the system will be pressure-tight for hydrostatic testing, and to allow equipment to be removed for maintenance without shutting down the system
- Provide isolating valves in all small lines branching from headers—for example, see figure 6.12
- Provide isolating valves at all instrument pressure points for removal of instruments under operating conditions
- Provide valved drains on all tanks, vessels, etc., and other equipment which may contain or collect liquids
- Protect sensitive equipment by using a fast-closing check valve to stop backflow before it can gather momentum
- Consider butt-welding or ring-joint flanged valves for lines containing hazardous or 'searching' fluids. Hydrogen is especially liable to leak
- Consider seal welding screwed valves if used in hydrocarbon service—see chart 2.3 (inset sketch)
- Provide sufficient valves to control flows
- Consider providing a concrete pit (usually about 4 ft x 4 ft) for a valve which is to be located below grade
- Consider use of temporary closures for positive shutoff—see 2.7
- Provide a bypass if necessary for equipment which may be taken out of service
- Provide a bypass valve around control stations if continuous flow is required. See 6.1.4 and figure 6.6. The bypass should be at least as large as the control valve, and is usually globe type, unless 6-inch or larger, when a gate valve is normally used (see 3.1.4, under 'Gate valve')
- Provide an upstream isolating valve with a small valved bypass to equipment which may be subject to fracture if heat is too rapidly applied on opening the isolating valve. Typical use is in steam systems to lessen the risk of fracture of such things as castings, vitreous-lined vessels, etc.
- Consider providing large gate valves with a valved bypass to equalize pressure on either side of the disc to reduce effort needed to open the valve

## PIPING SAFETY & RELIEF VALVES

- Refer to 3.1.9 for valve orientation
- Extend safety-valve discharge risers that discharge to atmosphere at least 10 ft above the roof line or platform for safety. Support the vent pipe so as not to strain the valve or the piping to the valve. Pointing the discharge line upward (see figure 6.4) imposes less stress when the valve discharges than does the horizontal arrangement
- The downstream side of a safety valve should be unobstructed and involve the minimum of piping. The downstream side of a relief or safety-relief valve is piped to a relief header or knockout drum—see 6.11.3, under 'Venting gases', and 6.12, under 'Relieving pressure—liquids'
- Pipe exhausting to atmosphere is cut square, not at a slant as formerly done, as no real advantage is gained for the cost involved
- Normally, do not instal a valve upstream of a pressure-relief valve protecting a vessel or system from excessive pressure. However, if an isolating valve is used to facilitate maintenance of a pressure-relief valve, the isolating valve is 'locked open'—sometimes termed 'car sealed open' (CSO)
- In critical applications, two pressure-relief valves provided with isolating valves can be used



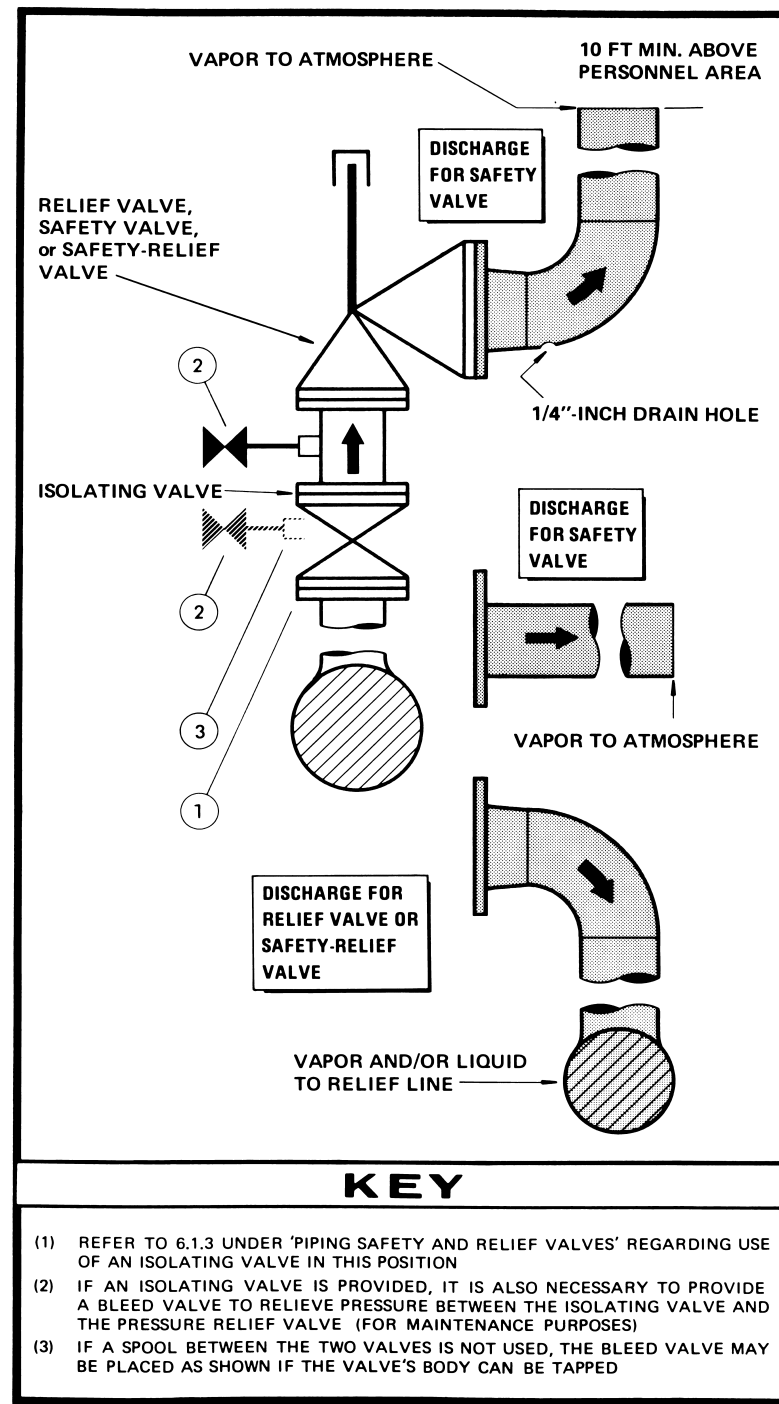
The installation of pressure-relieving devices and the use of isolating valves in lines to and from such devices is governed by the Code for Pressure Piping, ANSI B31 and the ASME Boiler and Pressure Vessel Code.

## INSTALLING BUTTERFLY VALVES

- Ensure that the disc has room to rotate when the valve is installed, as the disc enters the piping in the open position
- Place butterfly valves with integral gaskets between welding-neck or socket-welding flanges—see 3.1.6, under 'Butterfly valve'. The usual method of welding a slip-on flange (see figure 2.7) will not give an adequate seal, unless the pipe is finished smooth with the face of the flange

## PRESSURE-RELIEF-VALVE PIPING

FIGURE 6.4



### CONTROL (VALVE) STATIONS

### 6.1.4

A control station is an arrangement of piping in which a control valve is used to reduce and regulate the pressure or rate of flow of steam, gas, or liquid.



Control stations should be designed so that the control valve can be isolated and removed for servicing. To facilitate this, the piping of the stations should be as flexible as circumstances permit. Figure 6.5 shows ways of permitting control valve removal in welded or screwed systems. Figure 6.6 shows the basic arrangement for control station piping.

The two isolating valves permit servicing of the control valve. The emergency bypass valve is used for manual regulation if the control valve is out of action.

The bypass valve is usually a globe valve of the same size and pressure rating as the control valve. For manual regulation in lines 6-inch and larger, a gate valve is often the more economic choice for the bypass line—refer to 3.1.4, under 'Gate valve'.

Figures 6.7–11 show other ways of arranging control stations—many more designs than these are possible. These illustrations are all schematic and can be adapted to both welded and screwed systems.

### DESIGN POINTS

- For best control, place the control station close to the equipment it serves, and locate it at grade or operating platform level
- Provide a pressure-gage connection downstream of the station's valves. Depending on the operation of the plant, this connection may either be fitted with a permanent pressure indicating gage, or be used to attach a gage temporarily (for checking purposes)
- Preferably, do not 'sandwich' valves. Place at least one of the isolating valves in a vertical line so that a spool can be taken out allowing the control valve to be removed
- If the equipment and piping downstream of the station is of lower pressure rating than piping upstream, it may be necessary to protect the downstream system with a pressure-relief valve
- Provide a valved drain near to and upstream of the control valve. To save space, the drain is placed on the reducer. The drain valve allows pressure between the isolating valve(s) and control valve to be released. One drain is used if the control valve fails open, and two drains (one each side of the control valve) if the control valve fails closed
- Locate stations in rack piping at grade, next to a bent or column for easy supporting

### DRAFTING THE STATION

In plan view, instead of drawing the valves, etc., the station is shown as a rectangle labeled 'SEE DETAIL "X"' or 'DWG "Y"—DETAIL "X"', if the elevational detail appears on another sheet. See chart 5.7.

### UTILITY STATIONS

### 6.1.5

A utility station usually comprises three service lines carrying steam, compressed air and water. The steam line is normally ¾-inch minimum, and the other two services are usually carried in 1-inch lines. These services are for cleaning local equipment and hosing floors. (Firewater is taken from points fed from an independent water supply.)

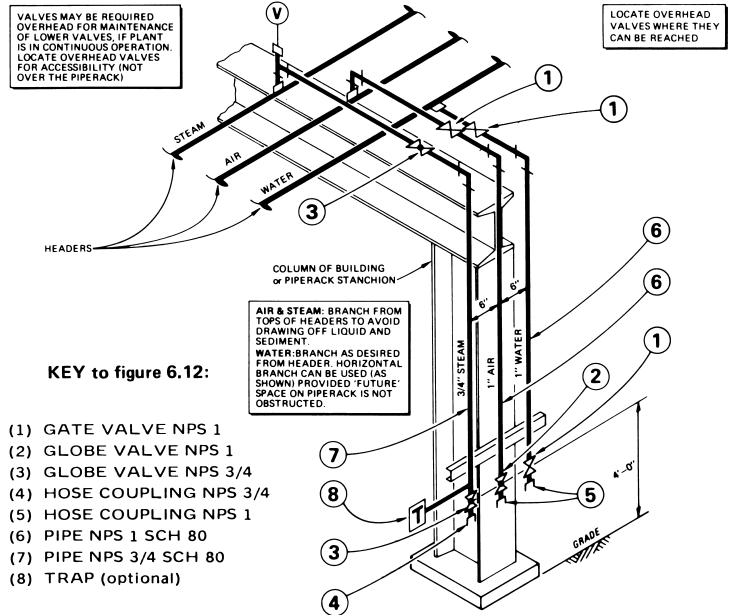
The steam line is fitted with a globe valve and the air and water lines with gate valves. All are terminated with hose connections about 3½ ft above floor or grade. A utility station should be located at some convenient steel column for supporting, and all areas it is to serve should be reachable with a 50-ft hose.

Most companies have a standard design for a utility station. Figure 6.12 shows a design for a standard station which can be copied onto one of the design drawings for reference, or otherwise supplied with the drawings to the erecting contractor who usually runs the necessary lines. A notation used on plan views to indicate the station and services required is:

| SERVICES:       | STEAM, AIR, WATER | AIR, WATER | STEAM, WATER | STEAM, AIR |
|-----------------|-------------------|------------|--------------|------------|
| STATION SYMBOL: | S A W             | A W        | S W          | S A        |

### UTILITY STATION

FIGURE 6.12

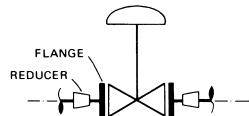


If subject to freezing conditions, utility station steam lines are usually trapped (otherwise, the trap can be omitted). Water is sometimes run underground in cold climates using an additional underground cock or plug valve with an extended key for operating, and a self-draining valve at the base of the riser. Another method to prevent freezing, is to run the water and steam lines in a common insulation.

# SCHEMATIC CONTROL STATION ARRANGEMENTS

## PIPING FITTINGS ALLOWING CONTROL VALVE REMOVAL

FLANGED CONTROL VALVES



THREADED CONTROL VALVES

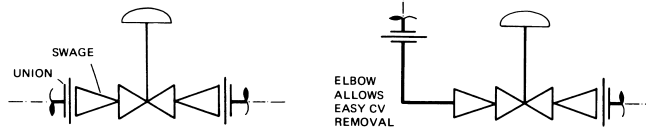
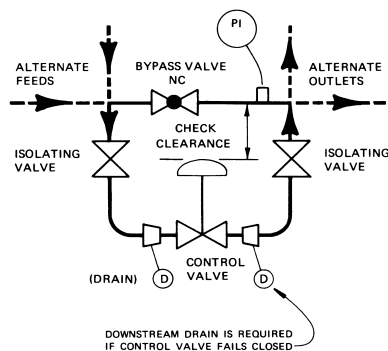


FIGURE 6.5

## BASIC ARRANGEMENT

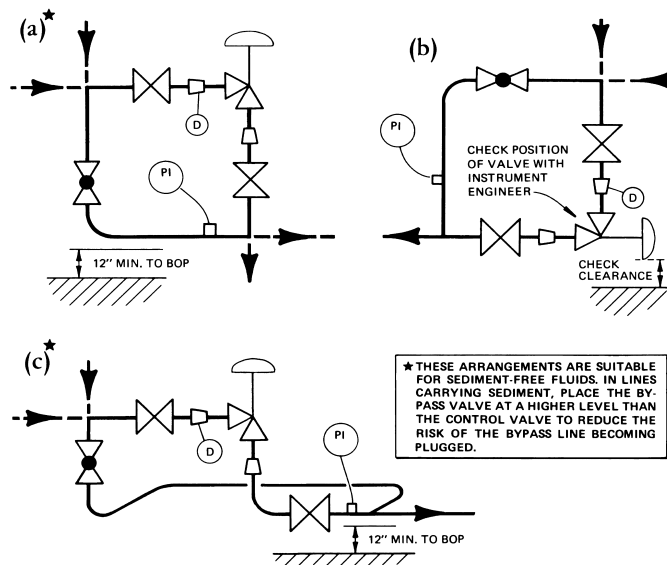
FIGURE 6.6



ISOLATING VALVES CAN BE THE SAME SIZE AS THE CONTROL VALVE  
SEE 6.1.3 UNDER 'WHICH SIZE VALVE TO USE'

## ARRANGEMENTS FOR ANGLE CV's

FIGURE 6.7



## STATIONS FOR LIQUIDS HARMFUL TO PERSONNEL

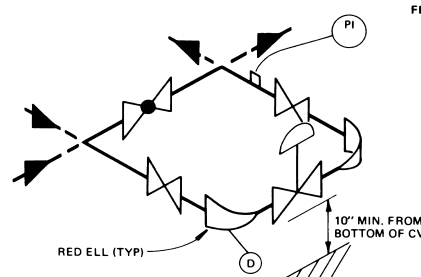
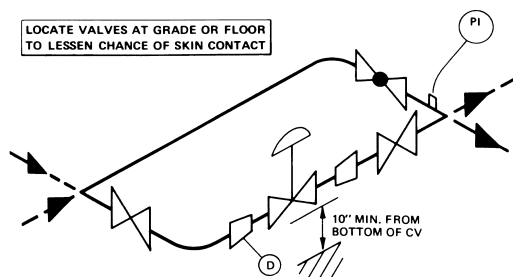


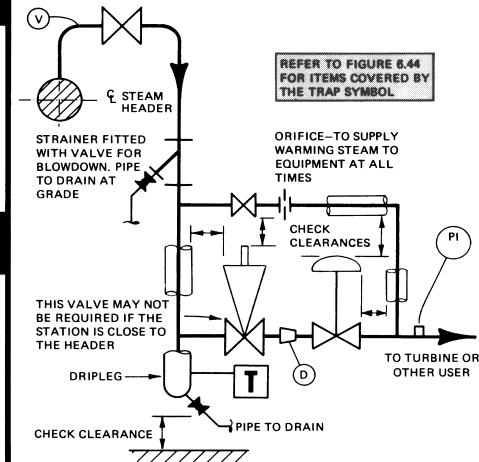
FIGURE 6.8

## FIGURES 6.5-6.11

## STEAM STATIONS

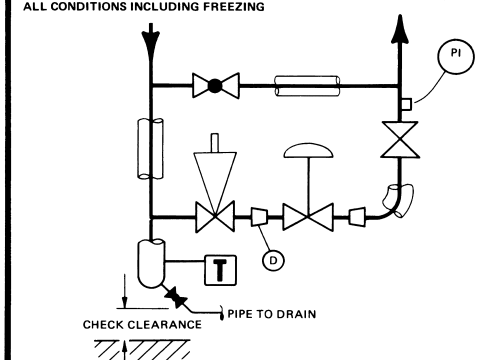
STATION SUITABLE FOR TURBINE & OTHER STEAM USERS

FIGURE 6.9



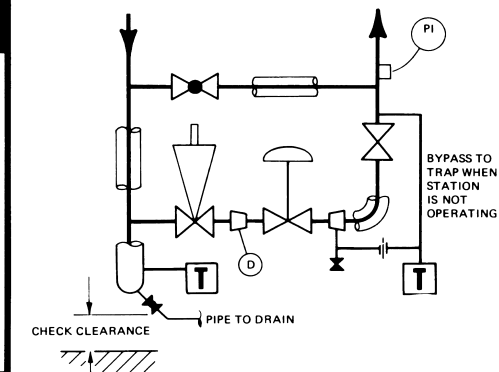
CONTINUOUSLY OPERATING STATION SUITABLE FOR ALL CONDITIONS INCLUDING FREEZING

FIGURE 6.10



STATION FOR INTERMITTENT USE SUITABLE FOR OPEN-AIR USE IN FREEZING CLIMATES

FIGURE 6.11



## ARRANGING SUPPORTS FOR PIPING

### 6.2

Pipe is held either from above by hangers or by supports of various types on which it rests. Hangers are also referred to as supports. Refer to 2.12 for typical hardware.

In the open, single pipes are usually routed so that they may be supported by fixtures to buildings or structures. A group of parallel pipes in the open is normally supported on a piperack—see 6.1.2.

Within a building, piping is routed primarily with regard to its process duty and secondarily with regard to existing structural steelwork, or to structural steel which may be conveniently added. Separate pipe-holding structures inside buildings are rare.

### FUNCTIONS OF THE SYSTEM OF SUPPORT

#### 6.2.1

The mechanical requirements of the piping support system are:

- (1) To carry the weight of the piping filled with water (or other liquid involved) and insulation if used, with an ample safety margin — use a factor of 3 (= ratio of load just causing failure of support or hanger to actual load) or the safety factor specified for the project. External loading factors to be considered are the wind loads, the probable weight of ice buildup in cold climates, and seismic shock in some areas
- (2) To ensure that the material from which the pipe is made is not stressed beyond a safe limit. In continuous runs of pipe, maximum tensile stress occurs in the pipe cross sections at the supports. Table S-1 gives spans for water-filled steel and aluminum pipe at the respective stress limits 4000 and 2000 psi. Charts S-2 give the maximum overhangs if a 3-ft riser is included in the span. The system of supports should minimize the introduction of twisting forces in the piping due to offset loads on the supports; the method of cantilevered sections set out in 6.2.4 substantially eliminates torsional forces
- (3) To allow for draining. Holdup of liquid can occur due to pipes sagging between supports. Complete draining is ensured by making adjacent supports adequately tilt the pipe—see 6.2.6
- (4) To permit thermal expansion and contraction of the piping—see 6.1.1, under 'Stresses on piping'
- (5) To withstand and dampen vibrational forces applied to the piping by compressors, pumps, etc.

### PIPING SUPPORT GROUP RESPONSIBILITIES

#### 6.2.2

A large company will usually have a specialist piping support group responsible for designing and arranging supports. This group will note all required supports on the piping drawings (terminal job) and will add drawings of any special details.

The piping support group works in cooperation with a stress analysis group—or the two may be combined as one group—which investigates areas of stress due to thermal movement, vibration, etc., and makes recommendations to the piping group. The stress group should be supplied with preliminary layouts for this purpose by the piping group, as early as possible.

Supports for lines smaller than 2-inch and non-critical lines are often left to the 'field' to arrange, by noting 'FIELD SUPPORT' on the piping drawings.

### LOADS ON SUPPORTS

Refer to tables P-1, which list the weights per foot of pipe and contained water (see 6.11.2). Weights of fittings, flanges, valves, bolts and insulation are given in tables W-1, compiled from suppliers' data.

### ARRANGING POINTS OF SUPPORT

#### 6.2.3

Pipe supports should be arranged bearing in mind all five points in 6.2.1. Inside buildings, it is usually necessary to arrange supports relative to existing structural steelwork, and this restricts choice of support points.

The method of support set out in 6.2.4 is ideal: In practice, some compromise may be necessary. The use of dummy legs and the addition of pieces of structural steel may be needed to obtain optimal support arrangements.

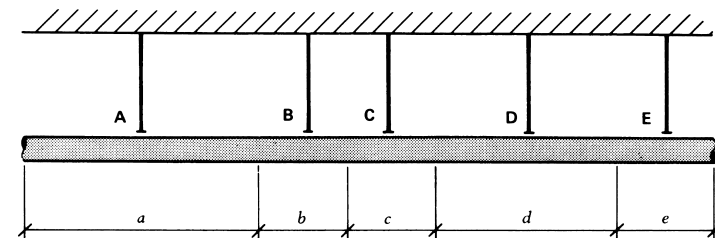
### CALCULATING PREFERRED POINTS OF SUPPORT

#### 6.2.4

Ideally, each point of support would be at the center of gravity of an associated length of piping. Carrying this scheme thru the entire piping system would substantially relieve the system from twisting forces, and supports would be only stressed vertically. A method of balancing sections of pipe at single support points is illustrated for a straight run of pipe in figure 6.13.

### BALANCING SECTIONS OF PIPE

FIGURE 6.13



Consider hanger B associated with a length of pipe  $b$ . This length of pipe is supported by B, located at its center of gravity, which is at the midway point for a straight length of uniform pipe. Hangers A, C, D and E are likewise placed at the respective centers of gravity of lengths of pipe  $a$ ,  $c$ ,  $d$  and  $e$ . If any length of pipe is removed, the balance of the rest of the line would be unaffected. Each of the hangers must be designed to adequately support the load of the associated piping—see 6.2.1, point (1).

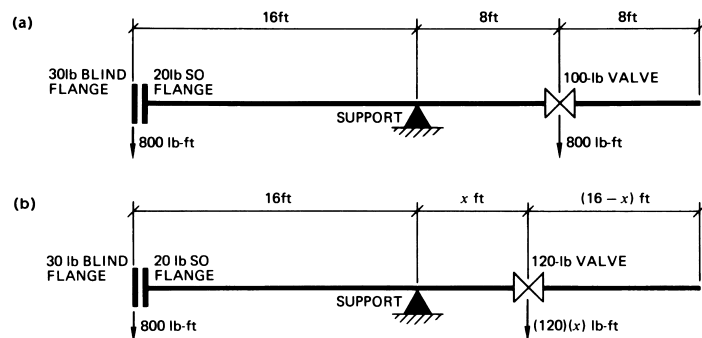
The presence of heavy flanges, valves, etc., in the piping will set the center of gravity away from the midpoint of the associated length. Calculation of support points and loadings is more quickly done using simple algebra. Answers may be found by making trial-and-error calculations, but this is much more tedious.

Correct location of piping supports can be determined by the use of 'moments of force'. Multiplying a force by the distance of its line of action from a point gives the 'moment' of the force about that point. A moment of force can be expressed in lb-ft (pounds weight times feet distance). The forces involved in support calculations either are the reactions at supports and nozzles, or are the downward-acting forces due to the weight of pipe, fittings, valves, etc.

In figure 6.14(a), the moment about the support of the two flanges is  $(30 + 20)(16) = 800$  lb-ft, counter-clockwise. The moment of the 100-lb valve about the support is  $(100)(8) = 800$  lb-ft, clockwise. As the lengths of pipe each side of the support are about the same, they may be omitted from the moment equation. The problem is simplified to balancing the valve and flanges.

#### USE OF MOMENTS

FIGURE 6.14



Suppose it was required to balance this length of piping with a 120 lb valve on the right—where should the 120 lb valve be placed?

Referring to figure 6.14(b), if  $x$  represents the unknown distance of the 120 lb valve from the support, the piping section would be in balance if:

$$(50)(16) = (120)(x).$$

That is, if  $x = (50)(16)/(120) = (800)/(120) = 6$  ft 8 in.

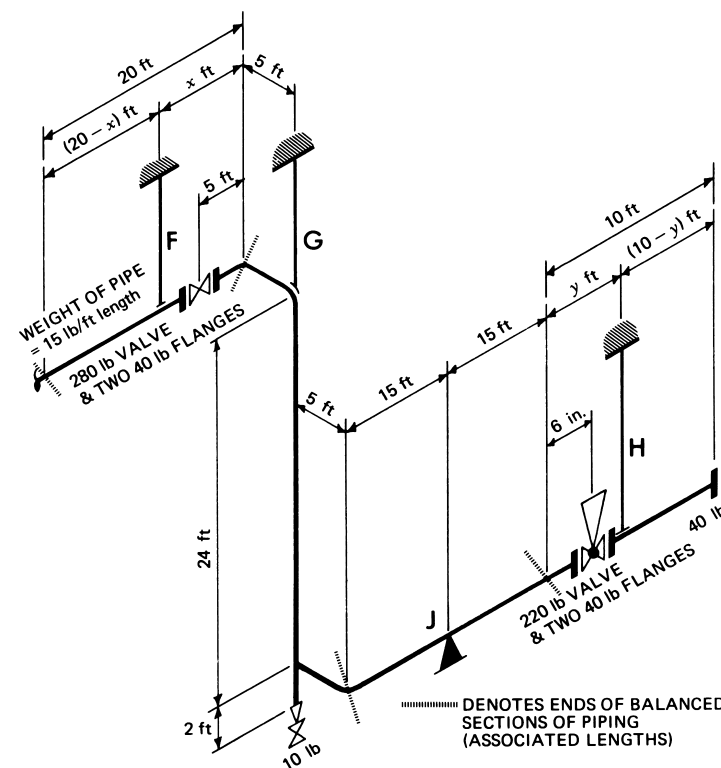
A more involved example follows:—

Figure 6.15 shows a length of 4-inch piping held by the hangers **F**, **G** and **H**, and support **J**. The lengths of associated piping are shown by dashed separation lines. The weights of pipe and fittings are shown on the drawing. The 4-inch pipe is assumed to weigh 15 lb per foot of length. Welded elbows and tees are assumed to weigh the same as line pipe.

First consider the section associated with hanger **F**. The weight of pipe to the left of **F** is  $(15)(20 - x)$  lb, and as its center of gravity is at  $(20 - x)/(2)$  ft, its moment on the hanger is  $(15)(20 - x)^2/(2)$  lb-ft. The heavy valve and flanges are assumed to have their mass center 5 ft from the end, and their moment is  $(x - 5)(360)$  lb-ft. Ignoring the pipe 'replaced' by the valve, the weight of pipe to the right of **F** is  $(15)(x)$  lb and its moment about **F** is  $(15)(x)(x)/(2)$  lb-ft. As the associated length is in balance:

#### CALCULATING PIPE SUPPORTS

FIGURE 6.15



$$(15)(20 - x)^2/(2) = (360)(x - 5) + (15)(x^2)/(2)$$

$$x = (80)/(11), \text{ or about } 7 \text{ ft } 3 \text{ in.}$$

The  $x^2$  terms canceled—this must be so, as there can physically be only one value for  $x$ . The load on hanger **F** is  $(20)(15) + (360)$  or 660 lb.

The support **J** should be at the center of the associated length of pipe, as already shown in figure 6.15, and the load on the support is  $(30)(15)$ , or 450 lb.

The hanger **G** is easily seen to be suitably placed, as there is 5 ft of 4-inch pipe overhanging each side. Only the load on the hanger need be calculated, which is  $(5 + 5 + 24 + 2)(15) + (10)$ , or 550 lb.

The location of hanger **H** has to be found by a calculation like that for hanger **F**, except that the heavy terminal flange has also to be taken into account. The moment equation in lb-ft is:

$$(300)(y - 0.5) + (15)(y^2)/(2) = (15)(10 - y)^2/(2) + (40)(10 - y)$$

which gives  $y$  as nearly 2 ft 8 in.

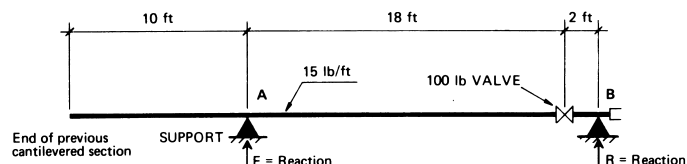
The load on hanger **H** is about  $(220) + (3)(40) + (15)(10)$ , or 490 lb.

## PROBLEM OF THE END

The supported length at one end of a run of piping may be cantilevered in the same way as the other lengths, and this has the advantage that if the piping terminates at a nozzle the load on the nozzle is minimal. However, it may be necessary to use or arrange a support at or near the end of a piping run. If the end of the run is vertical, the end support should be designed to carry the vertical run. The problem is usually more complex when the end of the run is horizontal.

The locations of fittings and support points will usually be already defined, and the problem is to calculate the reaction on the terminal support, and to see that the support is designed to withstand the load on it. In calculating the load on the terminal support, it should be made certain that the load *is* downward—with some arrangements, the piping would tend to raise itself off the terminal support (negative load) and if this type of arrangement is not changed, the terminal support will have to anchor the piping.

The sketch shows a horizontal end arrangement. Taking moments in lb-ft about the support A:



$$(15)(10)(\frac{1}{2})(10) = (15)(18 + 2)(\frac{1}{2})(18 + 2) + (100)(18) - (R)(18 + 2)$$

which gives

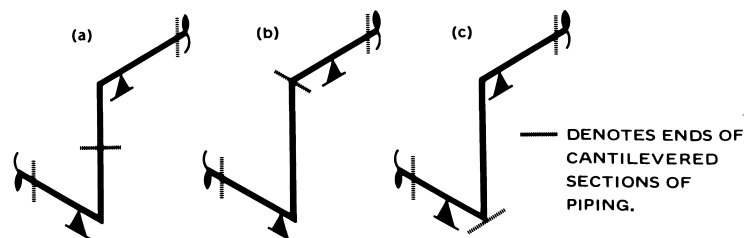
$$R = 202\frac{1}{2} \text{ lb.}$$

The reaction, F, on the support A can be calculated by taking moments about the support B or another axis, or more simply by equating vertical forces:

$$F + 202\frac{1}{2} = (15)(10 + 18 + 2) + 100 = 550, \text{ which gives } F = 347\frac{1}{2} \text{ lb.}$$

## PROBLEM OF THE RISER

Supports for lines changing in direction can be calculated by the cantilever method. Sketch (a) below shows that the weight of the vertical part of the piping can be divided between two cantilevered sections in any proportion suited to the available support points. Sketches (b) and (c) show the vertical piping associated wholly with the left- or right-hand cantilevered sections. The piping may be supported by means of a dummy leg, if direct support is not practicable.

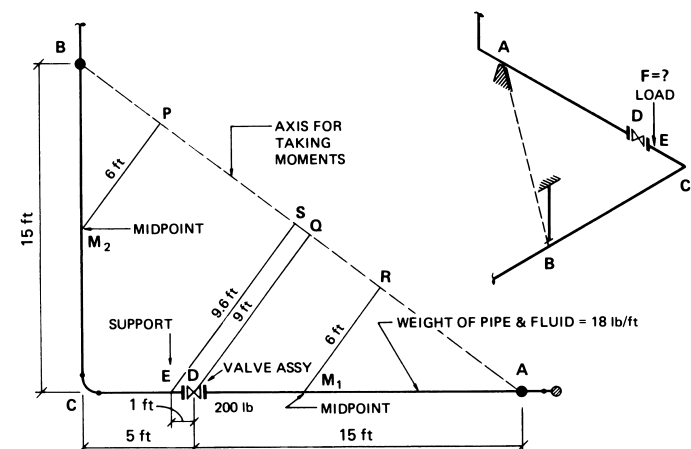


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## GRAPHIC METHOD FOR FINDING LOADS ON SUPPORTS

The following graphical method permits quick calculation of bearing loads for 'corner' piping arrangements.

**PROBLEM** To find the load to be taken by a support to be placed at point 'E' in the piping arrangement shown:



## SOLUTION

- Draw the plan view to any convenient scale (as above)
- Add the axis line AB (this must pass thru points of support)
- Divide the run of piping into parts. Piping between the support points A and B is considered in three parts: (1) The valve. (2) The length of pipe BC. (3) The length of pipe AC—the short piece of line omitted for the valve is ignored, and the effect of the elbow neglected.
- Drop perpendiculars from midpoints M<sub>1</sub> and M<sub>2</sub>, the valve and support point E to the axis line.
- Take moments about the axis line, measuring the lengths of perpendiculars M<sub>2</sub>P, ES, DQ and M<sub>1</sub>R directly from the plan view (these lengths are noted on the sketch):

| PIPE LENGTH AC |   | PIPE LENGTH CB |   | VALVE ASSY. |   | LOAD ON SUPPORT |
|----------------|---|----------------|---|-------------|---|-----------------|
| (20)(18)(6)    | + | (15)(18)(6)    | + | (200)(9)    | = | (F)(9.6)        |

which gives the load on the support at E as:

$$F = 581 \text{ lb}$$

## EXTENSION OF THE METHOD

The same method can be used if the angle at the corner is different from 90 degrees, or if vertical lines are included in the piping.

## NOTES

- The axis line must pass thru points of support. If the axis line is not horizontal, the lengths of the perpendiculars are still measured directly from the plan view.
- This method does not take into account additional moments due to bending and torsion of pipe. However, it is legitimate to calculate loads on supports as if the pipe is rigid.

This problem often occurs when running pipes from one piperack to another, with a change in elevation, as in figure 6.15. Too much overhang will stress the material of the pipe beyond a safe limit near one of the supports adjacent to the bend, and the designer needs to know the allowable overhang.

The stresses set up in the material of the pipe set practical limits on the overhangs allowed at corners. The problem is like that for spans of straight pipe allowable between supports. Overhangs permitted by stated limits for stress are given in charts S-2.

#### PIPE SUPPORTS ALLOWING THERMAL MOVEMENT

6.2.5

Piping subject to large temperature changes should be routed so as to flex under the changes in length—see figure 6.1. However, hangers and supports must permit these changes in length. Figures 2.72 A & B show a selection of hangers and supports able to accommodate movement. For single pipes hung from rod or bar hangers, the hanger should be sufficiently long to limit total movement to 10 degrees of arc.

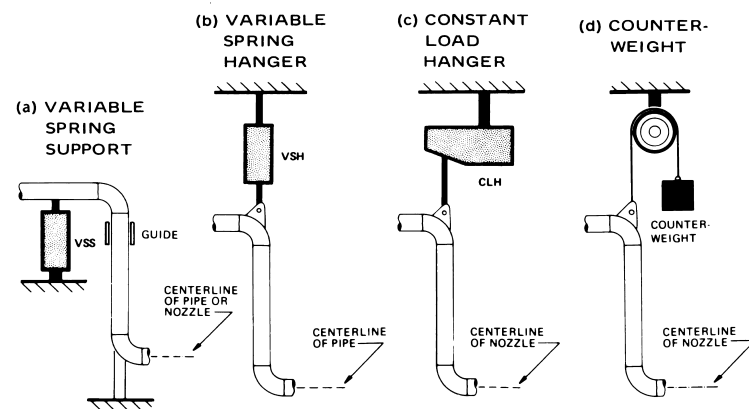
#### SPRING SUPPORTS

There are two basic types of spring support: (1) Variable load. (2) Constant load—refer to 2.12.2. Apart from cost, the choice between the two types depends on how critical the circumstances are. For example, if a vertical line supported on a rigid support at floor level is subject to thermal movement, a variable-spring hanger or support at the top of the line is suitable—see figure 6.16 (a) and (b).

If a hot line comes down to a nozzle connected to a vessel or machine, and it is necessary to keep the nozzle substantially free from vertical loading, a constant-load hanger can be used—see figure 6.16(c). Cheaper alternate methods of supporting the load are by a cable-held weight working over a pulley, as illustrated in figure 6.16(d), or by a cantilevered weight.

#### VARIABLE- & CONSTANT-LOAD HANGERS & SUPPORTS

FIGURE 6.16



#### SLOPED LINES AVOID POCKETING AND AID DRAINING

6.2.6

As pipe is not completely rigid, sagging between points of support must occur. In many instances, sagging is acceptable, but in others it must be restricted.

The nature of the conveyed material, the process, and flow requirements determine how much sagging can be accepted. Sagging is reduced by bringing adjacent points of support closer. Pocketing of liquid due to sagging can be eliminated by sloping the line so that the difference in height between adjacent supports is at least equal to triple the deflection (sag) at the mid-point. Lines which require sloping include blowdown headers, pressure-relief lines, and some process, condensate and air lines. (Air lines are discussed in 6.3.2, and draining of compressed-air lines in 6.11.4.)

Complete draining may be required for lines used in batch processing to avoid contamination, or where a product held in a line may degenerate or polymerize, or where solids may settle and become a problem.

In freezing conditions, lines conveying condensate from traps to drains are sloped; condensate headers may be sloped (as an alternative to steam tracing), depending on the rate of flow.

In the past, steam lines were sloped to assist in clearing condensate, but the improved draining is now not considered to be worth the difficulty and expense involved.

#### SLOPED LINES ON PIPERACKS

Sloped lines can be carried on brackets attached to the piperack stanchions (see figure 6.3). To obtain the required change in elevation at each bent, the brackets may be attached at the required elevations; alternately, a series of brackets can be arranged at the same elevation and the slope obtained by using shoes of different sizes—this method leads to fewer construction problems.

Shoes of graded sizes are also the best method for sloping smaller lines on the piperack. It is not usual or desirable to hang lines from the piperack unless necessary vertical clearances can be maintained.

#### SLOPED LINES IN BUILDINGS

Inside a building, both large and small sloped lines can rest on steel brackets, or be held with hangers. Rods with turnbuckles are used for hangers on lines required to be sloped. Otherwise, drilled flat bar can be used. (Adjustable brackets are available from the Unistrut and Kindorf ranges of support hardware.)

#### SUPPORTING PIPE MADE FROM PLASTICS OR GLASS

6.2.7

Pipe made either from flexible or rigid plastics cannot sustain the same span loads as metal pipe, and requires a greater number of support points. One way of providing support is to lay the pipe upon lengths of steel channel sections or half sections of pipe, or by suspending it from other steel pipes. The choice of steel section would depend on the span loads and the size and type of plastic pipe.

For glass process and drain lines, hangers for steel pipe are used, provided that they hold the pipe without causing local strains and are padded so as not to crack the pipe. Rubber and asbestos paddings are suitable. Uninsulated horizontal lines from 1 to 6 inch in size containing gas or liquid of specific gravity less than 1.3 should be supported at 8 to 10 ft intervals. Couplings and fittings should be about 1 ft from a point of support.

## DESIGN POINTERS

6.2.8

Terms such as 'dummy leg', 'anchor', 'shoe', etc., used in detailing supporting hardware are explained in 2.12.2. Refer to chart 5.7 for symbols.

### GENERAL

- Design hangers for 2½-inch and larger pipe to permit adjustment after installation
- If piping is to be connected to equipment, a valve, etc., or piping assembly that will require removal for maintenance, support the piping so that temporary supports are not needed
- Base load calculations for variable-spring and constant-load supports on the operating conditions of the piping (do not include the weight of hydrostatic test fluid)
- If necessary, suspend pipes smaller than 2-inch nominal size from 4-inch and larger pipes

### DUMMY LEGS

Table 6.3 suggests sizes for dummy legs. The allowable stress on the wall of the elbow or line pipe to which the dummy leg is attached sets a maximum length for the leg. The advice of the stress group should be sought.

APPROXIMATE SIZES FOR DUMMY LEGS

TABLE 6.3

| NPS of Piping (inches)        | 2  | 3 | 4 | 6 | 8 | 10 | 12 | 14 |
|-------------------------------|----|---|---|---|---|----|----|----|
| NPS of Pipe forming Leg (in.) | 1½ | 2 | 3 | 4 | 6 | 8  | 8  | 10 |
| Size of W-Flange (in.)        |    |   |   |   | 5 | 8  | 8  | 10 |

### ANCHORS

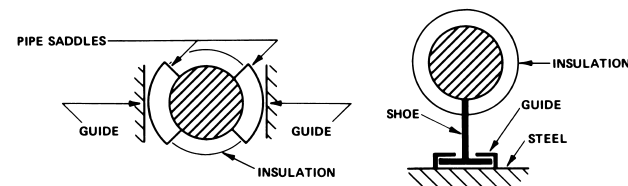
Anchors are required as stated in the following two points. However, advice from the stress and/or piping support groups should be obtained:

- Provide anchors as necessary to prevent thermal or mechanical movement overloading nozzles on vessels or machinery, branch connections, cast-iron valves, etc.
- Provide anchors to control direction of expansion; for example, at battery limits and on piping leaving units, so that movement is not transmitted to piping on a piperack

### SHOES, GUIDES, & SADDLES

- Do not use shoes on uninsulated pipes, unless required for sloping purposes. For reduced friction where lines are long and subject to movement, slide plates are an alternative—see 2.12.2.
- Use of wye-type shoes enables pipes to be placed on the shoe before welding and makes construction easier — see figure 2.72A
- Welding the pipe directly to shoes is not always acceptable; for example with rubber-lined pipe. Bolted or strapped shoes are more suitable

- Check the code pertinent to the project, as it may prohibit 'partial' welds for supports—that is, welds that do not encircle the pipe
- Provide slots in shoes to accept the straps or wires used to hold insulation to pipe
- Provide guides for long straight pipes subject to thermal movement, either by guiding the shoe or by guiding pipe support saddles attached to the pipe, as shown:



- For better stress distribution in the pipe wall, pipe support saddles are usually used on large lines. They can also be used for lines that may twist over when moving

### SUPPORTING VALVES

- Provide support as close as possible to heavy valves, or try to get valves moved close to a suitable point where support can be provided
- Large valves and equipment such as meters located at grade will usually require a concrete foundation for support

### WELDING PIPE-SUPPORT & PLATFORM BRACKETS TO VESSELS, Etc.

- Instruct the vendor to add brackets required on pressure vessels prior to stress-relieving and testing—otherwise, retesting and recertification may be obligatory
- It is permissible to specify brackets to be welded to non-pressure vessels provided that the strength of the vessel is not degraded

### SUPPORTING PIPE AT NOZZLES

Ensure that nozzles on machinery, compressors, pumps, turbines, etc., are substantially free from loads transmitted by the piping, which may be due to the weight of the piping, or to movement in the piping resulting from contraction, expansion, twisting, vibration or surging. Equipment suppliers will sometimes state maximum loadings permissible at nozzles. ***Excessive loads applied to nozzles on machinery can force it from alignment and may cause damage.***

Piping to pumps, turbines, etc., should be supported adequately, but should allow the equipment to be removed. Supports for this piping are best made integral with the concrete foundations, especially if thermal movement occurs and should be on the same level as the base of the equipment, so that on heating or cooling, vertical differential expansion and contraction between supports and equipment will be minimized.

## PUMP EMPLACEMENT & CONNECTIONS

## 6.3.1

### TYPICAL PIPING FOR CENTRIFUGAL PUMPS

Most pumps used in industry are of the centrifugal type. Figures 6.17 and 6.18 show typical piping and fittings required at a centrifugal pump together with the valves necessary to isolate the pump from the system.

The check valve is required to prevent possible flow reversal in the discharge line. A permanent in-line strainer is normally used for screwed suction piping and a temporary strainer for butt-welded/flanged piping. The temporary strainer is installed between flanges—see figure 2.69. A spool is usually required to facilitate removal.

Although centrifugal pumps are provided with suction and discharge ports of cross-sectional area large enough to cope with the full rated capacity of the pump, it is often necessary with thick fluids or with long suction lines to use an inlet pipe of larger size than the inlet port, to avoid cavitation. Cavitation is the pulling by the pump of vapor spaces in the pumped liquid, causing reduction of pumping efficiency, noisy running, and possible impellor and bearing damage. Refer to 6.1.3, under ‘Which size valve to use?’.

Most pumps have end suction and top discharge. Limitations on space may require another configuration, such as top suction with top discharge, side suction with side discharge, etc. Determination of nozzle orientation takes place when equipment layout and piping studies are made.

### AUXILIARY, TRIM, or HARNESS PIPING

Pumps, compressors and turbines may require water for cooling bearings, for mechanical seals, or for quenching vapors to prevent their escape to atmosphere. Piping for cooling water or seal fluid is usually referred to as auxiliary, trim, or harness piping, and the requirement for this piping is normally shown on the P&ID. This piping is usually shown in isometric view on one of the piping drawings.

In order to cool the gland or seal of a centrifugal pump and ensure proper sealing, it is usually supplied with liquid from the discharge of the pump, by a built-in arrangement, or piped from a connection on the pump’s casing. The gland may be provided with a cooling chamber, requiring piped water. If a pump handles hot or volatile liquid, seal liquid may be piped from an external source.

### DRAINING

Each pump is usually provided with a drain hub 4 to 6 inches in diameter, positioned about 9 inches in front of the pump foundation on the centerline of the pump. The drain hub is piped to the correct sewer or effluent line—see 6.13. If two small pumps have a common foundation, they can share the same drain hub.

Most centrifugal pumps have baseplates that collect any leakage from the pump. The baseplate will have a threaded connection which is piped to the drain hub. Waste seal water is also piped to the drain hub—see figure 6.19.



- In outside installations in freezing climates, provide a valved drain from the pump’s casing
- Provide a short spool for a 3/4-inch drain between the on/off valve and the check valve, to drain the discharge line. If the valve is large enough, the drain can be made by drilling and tapping a boss on the check valve, as shown in figure 6.17, note (3), in which instance no spool is required.

### INSTALLATION

- Do not route piping over the pump, as this interferes with maintenance. It is better to bring the piping forward of the pump as shown in figure 6.17
- Leave vertical clearance over pumps to permit removal for servicing—sufficient headroom must be left for a mobile crane for all but the smaller pumps, unless other handling is planned
- If pumps positioned close to supply tanks are on separate foundations, avoid rigid piping arrangements, as the tanks will ‘settle’ in the course of time
- Locate the pump as closely as practicable to the source of liquid to be pumped from storage tanks, sumps, etc., with due consideration for flexibility of the piping
- Position valves for ease of operation placing them so they are unlikely to be damaged by traffic and will not be a hazard to personnel—see table 6.2 and chart P-2
- The foundation may be of any material that has rigidity sufficient to support the pump baseplate and withstand vibration. A concrete foundation built on solid ground or a concrete slab floor is usual. The pump is positioned, the height fixed (using packing), and the grout is then poured. Grout thickness is not usually less than one inch—see figure 6.17
- A pit in which a pump is installed should have a drain, or have a sump that can be drained or pumped out
- Make the concrete foundation at least as large as the baseplate, and ensure that concrete extends at least 3 inches from each bolt

### VALVES

- Valves are ‘line size’ unless shown otherwise on the P&ID. See 6.1.3 under ‘Which size valve to use?’
- Use tilting disc or swing check valves for preference
- Do not use globe valves for isolating pumps. Suction and discharge line isolating valves are usually gate valves, but may be other valves offering low resistance to flow

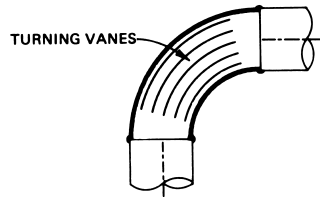
## SUCTION LINE

To avoid cavitation, the pump must be at the correct elevation, related to the level or head of the liquid being pumped. If the location of the pump has not previously been established on an equipment arrangement drawing, refer to the engineer involved.

Concentric reducers are used in lines 2-inch and smaller. Eccentric reducers are used in lines 2½-inch and larger, and are arranged to avoid: (1) Creating a vapor space. (2) Creating a pocket which would need to be drained. These conditions set the configuration of the reducer—that is, whether it is to be installed 'top flat' or 'bottom flat'.

If a centrifugal pump has the suction nozzle at the end (in line with the drive shaft), an elbow may be connected directly to the nozzle at any orientation.

If a pump has the suction nozzle at the side with split flow to the impellor provide a straight run of pipe equal to 3 to 5 pipe diameters of the suction line to connect to the nozzle. Alternately, an elbow may be connected to the suction nozzle, but it must be arranged in a plane at 90 degrees to the driving shaft, to promote equal flow to both sides of the impellor. If an elbow must be in the same plane as the driving shaft of the pump, consider the use of turning (or splitter) vanes to induce more even flow. Uneven flow causes damage to the impellor and bearings.



- Route suction lines as directly as possible so as not to starve the pump and incur the risk of cavitation
- If the pump draws liquid from a sump at a lower elevation, provide a combined foot valve and strainer. A centrifugal pump working in this situation requires priming initially—provide for this by a valved branch near the inlet port, or by other means
- Provide a strainer in the suction line—see figures 6.17 thru 6.21. Do not place a temporary startup screen immediately downstream of a valve, as debris may back up and prevent the valve from being closed

## DISCHARGE LINE

The outlet pipe for centrifugal and other non-positive displacement pumps is in most cases chosen to be of larger bore than the discharge port, in order to reduce velocity and consequent pressure drop in the line. A concentric reducer or reducing elbow is used in the discharge line to increase the diameter. There is no restriction on the placement of elbows in discharge lines as there is in suction lines.

- Provide a pressure connection in the discharge line, close to the pump outlet — see figures 6.17 thru 6.21. It may be necessary to provide a short spool for this purpose if there is no pressure point tapping on the pump discharge nozzle
- For locations of drain connections in the discharge line, see figures 6.17 thru 6.21

## PUMPS WITH SCREWED CONNECTIONS

A pump with screwed connections requires unions in the suction and discharge lines to permit removal of the pump.

## PIPING FOR POSITIVE-DISPLACEMENT PUMPS

Reciprocating and rotary pumps of this type must be protected against overloading due to restriction in the discharge line. If a positive-displacement pump is not equipped with a relief valve by the manufacturer, provide a relief valve between the pump discharge nozzle and the first valve in the discharge line. The discharge from the relief valve is usually connected to the suction line between the isolating valve and the pump.

As positive displacement pumping does not greatly change the flow velocity, reducers and increasers are not usually required in suction and discharge lines. See figures 6.20 and 6.21. A positive-displacement pump having a pulsating discharge may set the piping into vibration, and to reduce this an air chamber (pneumatic reservoir) such as a standpipe can be provided downstream of the discharge valve.

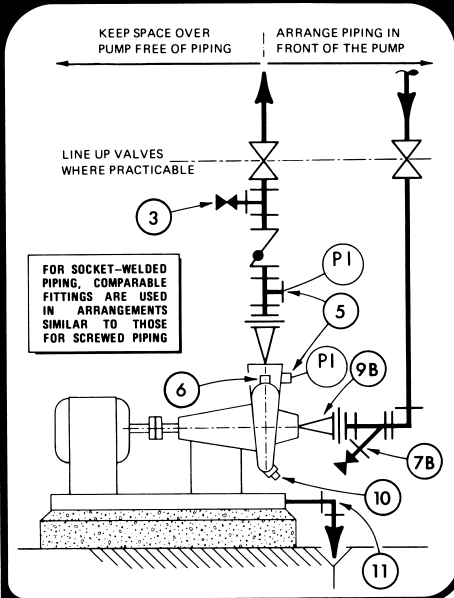
## KEEPING MATERIAL FROM SOLIDIFYING IN THE PUMP

It may be necessary to trace a pump (see 6.8.2) in order to keep the conveyed material in a fluid state, especially after shutdown. This problem arises either with process material having a high melting point, or in freezing conditions. Alternately, jacketed pumps can be employed (such as Foster jacketed pumps available from Parks-Cramer).

**FIGURES 6.17 THRU 6.21 ARE ON THE FOLLOWING THREE PAGES, & THE KEY FOR THESE FIGURES IS ON THE THIRD OF THESE PAGES**

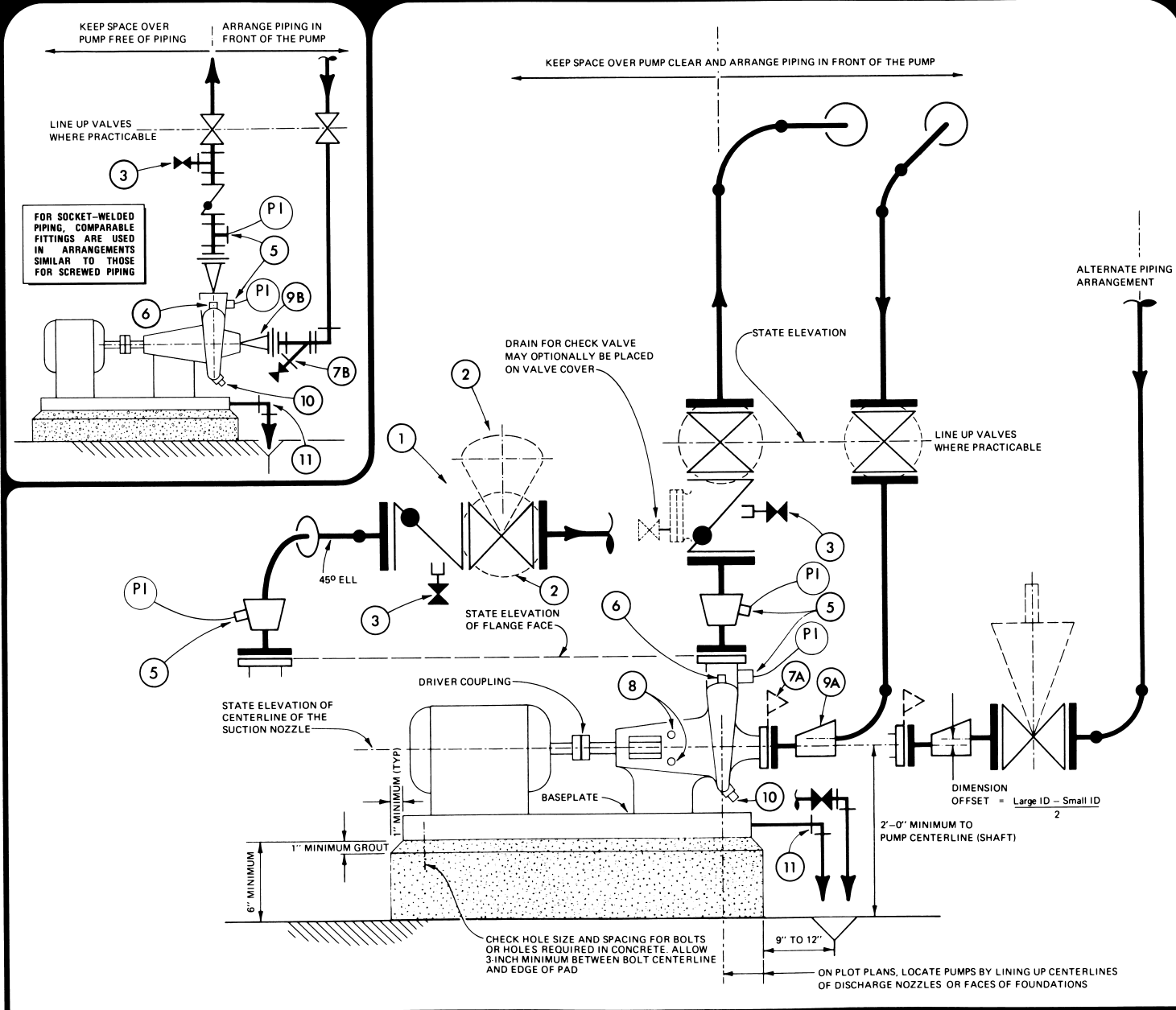
# CENTRIFUGAL PUMP PIPING IN ELEVATION

SCREWED PIPING FIGURE 6.18



FLANGED BUTT-WELDED PIPING

FIGURE 6.17

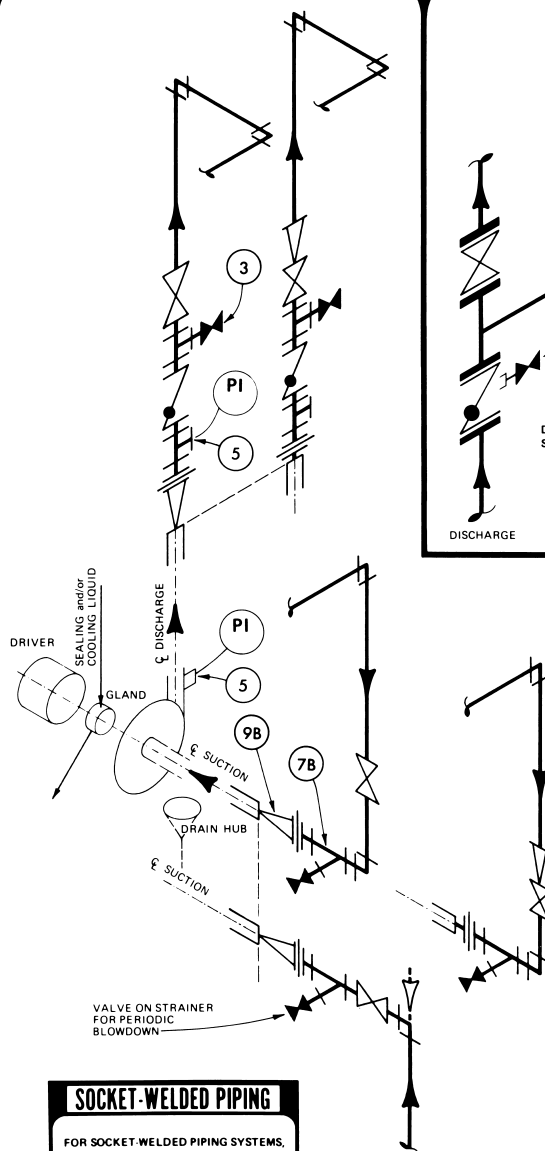


# PIPING TO CENTRIFUGAL PUMPS—ALTERNATIVES

REFER ALSO TO 6.1.3, 'WHICH SIZE VALVE TO USE'

FIGURE 6.19

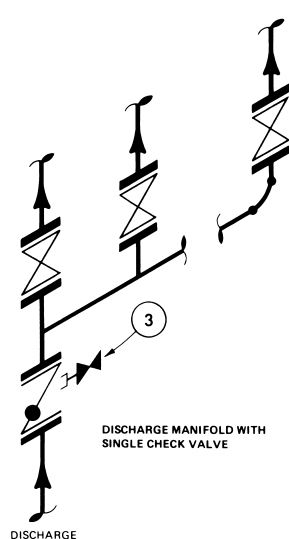
## SCREWED PIPING



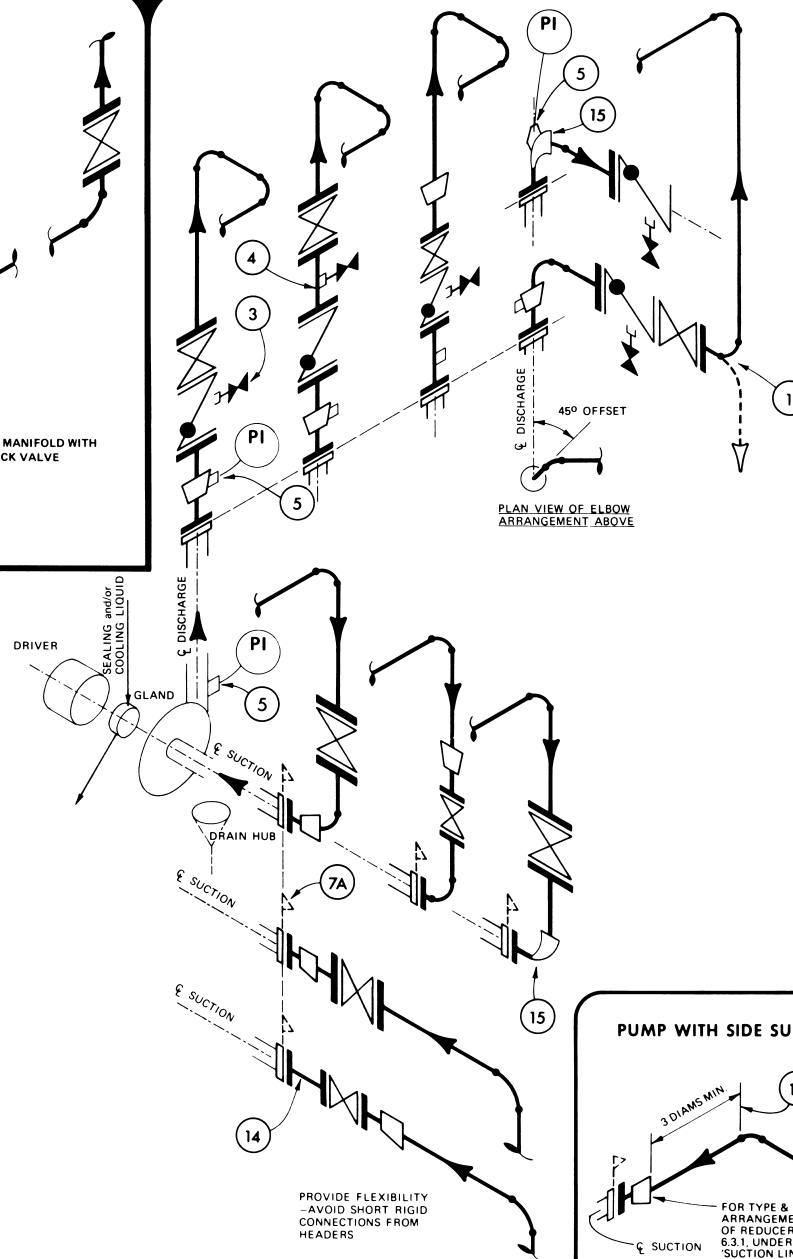
## SOCKET-WELDED PIPING

FOR SOCKET-WELDED PIPING SYSTEMS, COMPARABLE FITTINGS ARE USED IN SIMILAR ARRANGEMENTS TO THOSE SHOWN HERE

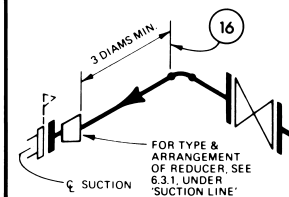
## DISCHARGE MANIFOLD



## FLANGED BUTT-WELDED PIPING

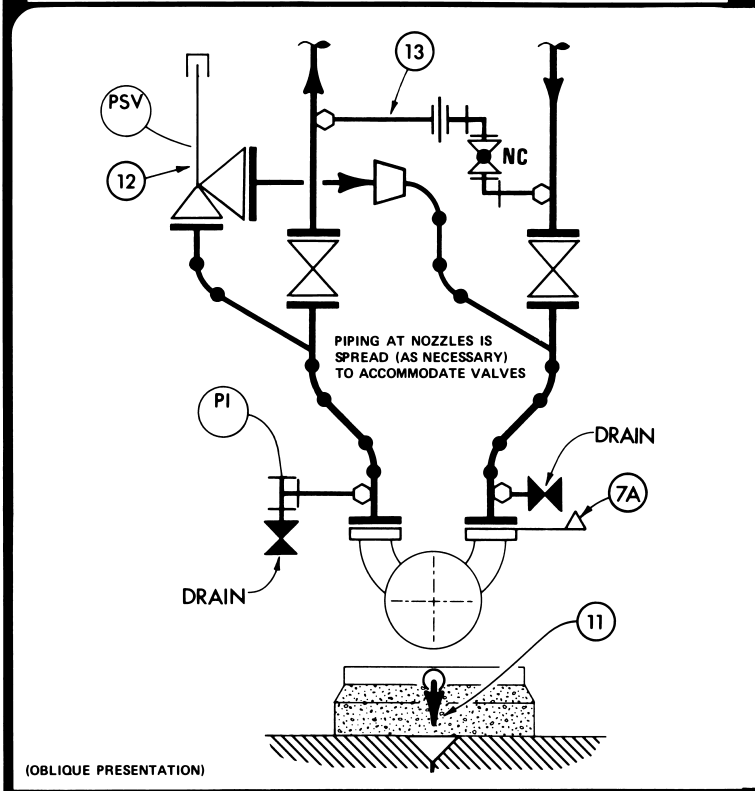


## PUMP WITH SIDE SUCTION



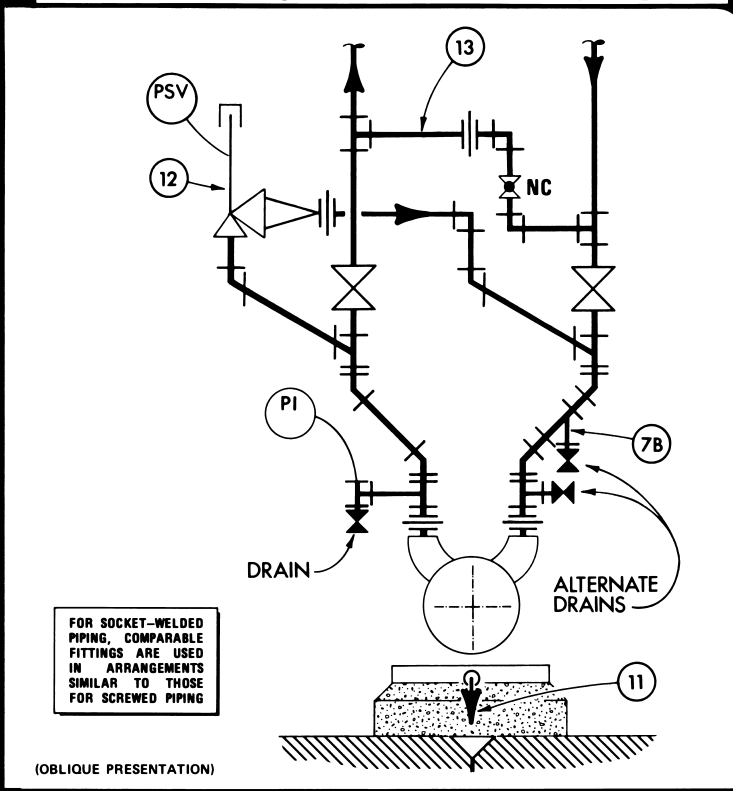
# PIPING FOR POSITIVE-DISPLACEMENT PUMPS

## FLANGED BUTT-WELDED PIPING FIGURE 6.20



## SCREWED PIPING

## FIGURE 6.21



KEY FOR  
FIGURES  
6.17-6.21

- (1) ALTERNATE HORIZONTAL DISCHARGES, WITH LINE OFFSET AND WITH VALVES LAID OVER AND OFFSET AS NECESSARY—THIS MAY BE NECESSARY IF THE VERTICAL POSITION PLACES HANDWHEEL OUT OF REACH OR IF DISCHARGE NEEDS TO TURN DOWN
- (2) ALTERNATE POSITIONS FOR HANDWHEEL
- (3) PROVIDE 1/2 TO 3/4-INCH DRAIN ON CHECK VALVE ABOVE DISC (A DRAINPOINT OR BOSS IS USUALLY PROVIDED ON 2-INCH AND LARGER VALVES) AND RUN LINE TO DRAIN. OTHERWISE, PLACE DRAIN ON SPOOL BETWEEN CHECK AND ISOLATING VALVES. ON SCREWED AND SOCKET-WELDED PIPING, PROVIDE A TEE FOR THE DRAIN CONNECTION
- (4) SPOOL FOR DRAIN POINT, IF DRAIN CANNOT GO ON CHECK VALVE
- (5) ALTERNATE PRESSURE GAGE POINTS ON DISCHARGE PIPING IF POINT IS NOT PROVIDED ON PUMP BY VENDOR
- (6) CASING VENT. CAN BE USED FOR SEAL LIQUID TAKEOFF
- (7 A) TEMPORARY STARTUP STRAINER
- (7 B) PERMANENT LINE STRAINER FOR SCREWED OR SOCKET-WELDED PIPING
- (8) CONNECTIONS FOR COOLING OR SEAL LIQUID. USUALLY WATER OR OIL

- (9 A) REDUCER
- (9 B) SWAGE (SWAGED NIPPLE) { CONCENTRIC TYPES MAY BE USED ON PUMPS WITH INLET PORTS 2-INCH AND SMALLER
- (10) CASING DRAIN PLUG. RUN VALVED LINE IF LIQUID IS LIKELY TO FREEZE
- (11) PIPE BASEPLATE OF PUMP TO DRAIN HUB. PROVIDE HUB AT EACH PUMP. PIPE HUB TO APPROPRIATE DRAIN OR SEWER. IF TWO PUMPS ARE ON A COMMON BASE, THEY CAN SHARE THE SAME HUB
- (12) BYPASS PROTECTS POSITIVE-DISPLACEMENT PUMP AND DRIVER IF AN ATTEMPT IS MADE TO OPERATE PUMP WITH A DISCHARGE VALVE CLOSED
- (13) BYPASSES FOR PUMPS OPERATING IN PARALLEL ALLOW FLOW IN SUCTION AND DISCHARGE LINES TO A HEADER IF A PUMP IS SHUT DOWN
- (14) SPOOL FOR TEMPORARY STRAINER
- (15) REDUCING ELBOW MAY REPLACE REGULAR ELBOW AND REDUCER
- (16) IF A PUMP HAS SIDE SUCTION WITH SPLIT FLOW TO IMPELLOR, PROVIDE 3 OR MORE DIAMETERS OF STRAIGHT PIPE AS SHOWN, OR CONNECT AN ELBOW IN A PLANE AT 90 DEGREES TO THE IMPELLOR SHAFT

## COMPRESSOR PIPING

### 6.3.2

Refer to 3.2.2 for a description of compressors and associated equipment. A compressor supplies compressed air or a gas to process or other equipment. A compressor is usually purchased as a 'package unit', which includes coolers, and the designer is left with the problem of installing it and piping auxiliaries to it. These various auxiliaries are shown in figure 6.23.

Compressors may be installed in the open, or within a plant or separate compressor house. An arrangement of compressor, ancillary equipment and distribution lines is shown in figure 6.22 (derived from an illustration by Atlas Copco).

### COMPRESSOR HOUSE

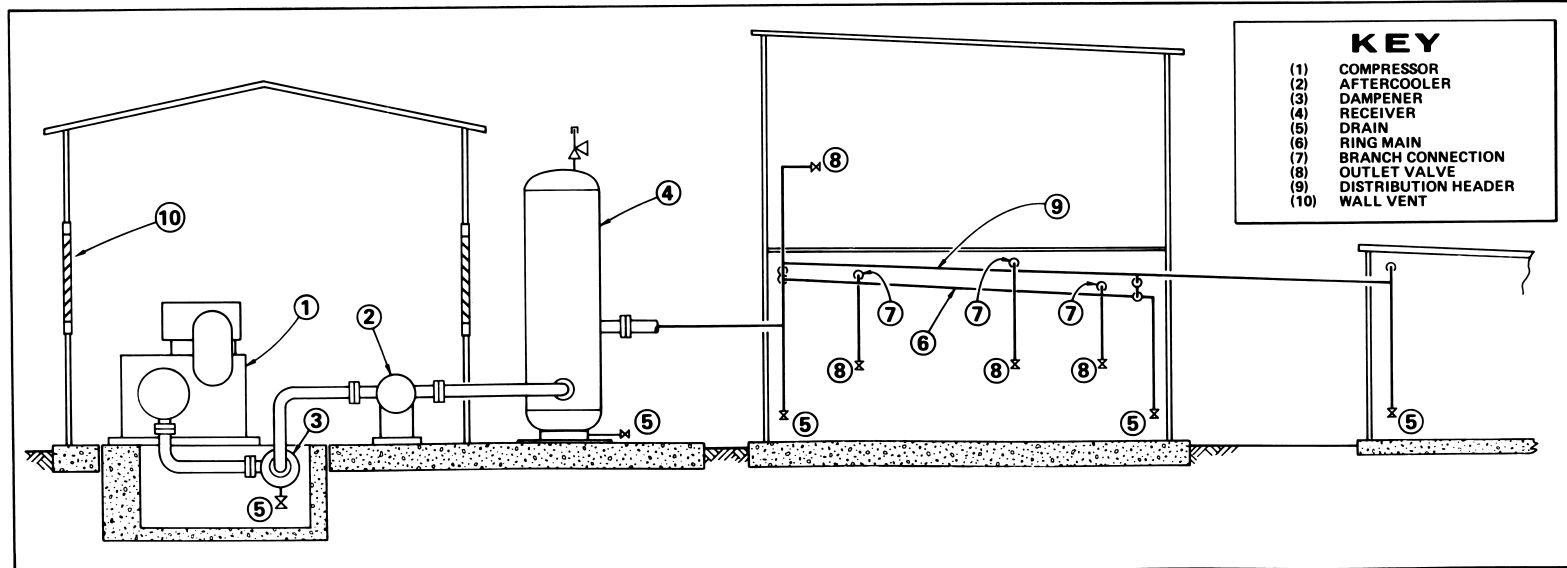
- If the compressor is handling a gas heavier than air, eliminate pits or trenches in the compressor house to avoid a suffocation or explosion risk
- Provide air entry louvers if a compressor takes air from within a compressor house or other building
- Provide maintenance facilities, including a lifting rail or access for mobile lifting equipment. Allow adequate floor space for use during maintenance. Additional access may be required for installation
- Prevent transmission of vibration by providing a foundation for the compressor, separate from the compressor-house foundation
- Consider the use of noise-absorbing materials and construction for a compressor house

The vendor's drawings should be examined to determine what auxiliary piping, valves and equipment covered in the following design points are to be supplied with the compressor by the vendor:

## COMPRESSOR & PIPING LAYOUT

- Install the compressor on a concrete pad or elevated structure. Piling is often a necessary part of the foundation
- Large reciprocating compressors are often installed on an elevated structure to allow access to valves and provide space for piping. Provide a platform for operation and maintenance of such an installation
- Keep piping clear of cylinders of reciprocating compressors and provide withdrawal space at cylinder heads
- Use long-radius elbows or bends, not short-radius elbows or miters
- If the compressor and the pressurized gas are cooled with water, route cooling water first to the aftercooler, then to the intercooler (for a two-stage machine), and lastly to the cylinder jackets (or casing jacket, if present, in other types of compressor)
- Arrange an air compressor, associated equipment and piping so that water is able to drain continuously from the system
- Pipe a separate trapped drain for each pressure stage. Ensure that the pressure into which any trap discharges will be lower than that of the system being drained—less the pressure drop over the trap and its associated piping. Do not pipe different pressure stages thru separate check valves to a common trap
- If a toxic or otherwise hazardous gas is to be compressed, vent possible shaft seal leakage to the suction line to avoid a dangerous atmosphere forming around the compressor
- Do not overlook substantial space required for lube oil and seal oil control consoles for compressors
- Discuss piping arrangement with the stress group

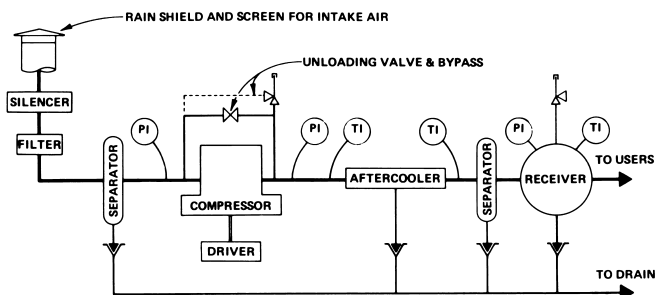
FIGURE 6.22



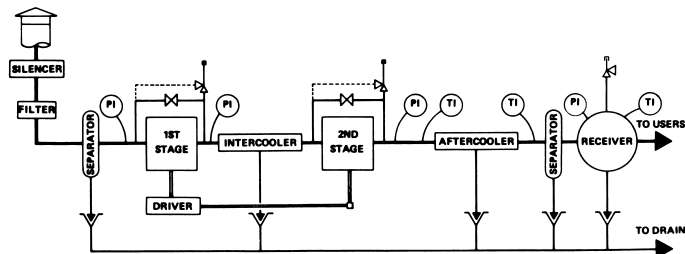
## SCHEMATIC ARRANGEMENTS OF COMPRESSED-AIR EQUIPMENT

FIGURE 6.23

### (a) SINGLE-STAGE COMPRESSOR



### (b) TWO-STAGE COMPRESSOR



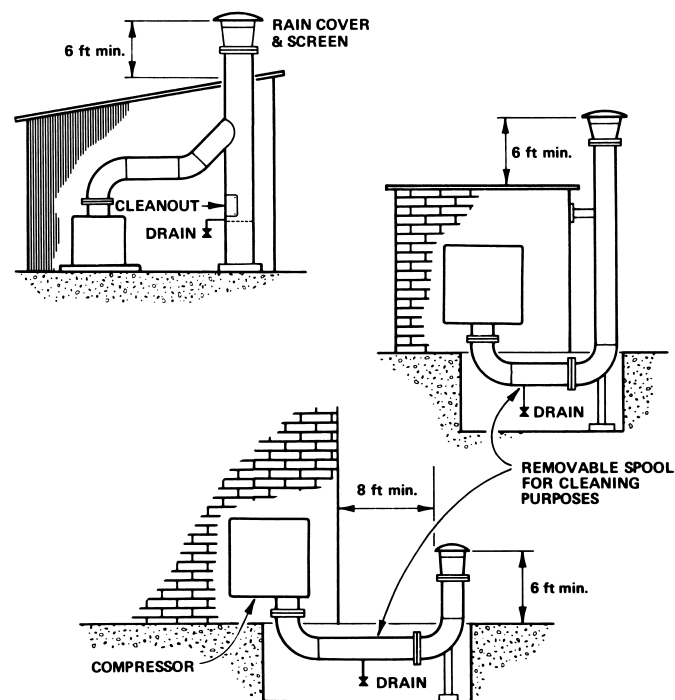
## SUCTION PIPING FOR AIR COMPRESSORS

- To reduce damage to a compressor by abrasion or corrosion, the air supply needs to be free from solids and water (water in the air intake does not affect operation of liquid-ring air compressors). Air intakes are best located where the atmosphere is uncontaminated by exhaust gases, industrial operations, or by traffic
- For efficiency the air supply should be taken from the coolest source such as the shaded side of a building, keeping to building clearances shown in figure 6.24
- If the air supply is from outside the building, locate the suction point above the roofline, and away from walls to avoid excessive noise
- Keep suction piping as short as possible. If a line is unavoidably long and condensate likely to form, provide a separator at the compressor intake
- Provide a rain cover and screen as shown in figure 6.24
- Small (and sometimes medium-sized) air compressors usually take air from inside a building. Large air compressors take air from outside a compressor house (figure 6.24): this minimizes effects on the building of pulsations radiated from the air inlet. In both instances, a filter is needed to remove dust, which is always present to some extent
- Filters must have capacity to retain large quantities of impurities with low pressure drop, and must be rugged enough to withstand pulsations from reciprocating compressors

- Provide a pressure gage connection between filter and compressor to allow the pressure drop across the filter to be measured in order to check when cleaning or replacement is needed
- Use a temporary screen at the compressor inlet at startup—see 2.10.4
- Avoid low points in suction lines where moisture and dirt can collect. If low points cannot be avoided, provide a clean-out—see figure 6.24
- If the suction line is taken from a header, take it from the top of the header to reduce the chance of drawing off moisture or sediment
- A line-size isolating valve is required for the suction line if the suction line draws from a header shared with other compressors
- Consider pickling or painting the inside of the suction piping to inhibit rust formation and lessen the risk of drawing rust into the compressor

## SUCTION LINES TO AIR COMPRESSORS

FIGURE 6.24



## DISCHARGE PIPING (GENERAL)

Discharge piping should be arranged to allow for thermal movement and draining. Anchors and braces should be provided to suppress vibration. The outflow from the aftercooler will usually be wet (from the excess moisture in suction air) and this water must be continually removed.

- An isolating valve in the discharge line is line-size
- Provide discharge piping with connections for temperature and pressure gages
- Provide an unloading valve and bypass circuit connected upstream of the discharge isolating valve, and downstream of the suction isolating valve, so as to ensure circulation thru the compressor during unloading, and to permit equalizing pressure in the compressor—see 3.2.2, under ‘Unloading’
- Normally locate a receiver close to the compressor. (Auxiliary receivers may be located near points of heavy use.)
- For draining compressed-air discharge lines, refer to 6.11.4



The use of dampeners and volume bottles in the discharge is discussed in 3.2.2, under ‘Equipment for compressors’.

### **LOADS & VIBRATION**

The design of supports for piping to large compressors (especially for reciprocating machines) requires special knowledge. Usually, collaboration is necessary with the piping support group, the stress group, and the compressor manufacturer’s representative. A major problem is that the compressor may be forced from alignment with its driver if the piping and supports are not properly arranged.

If a diesel or gasoline engine is used as driver, a flexible joint on the engine’s exhaust pipe will reduce transmission of vibration, and protect the exhaust nozzle. Flexible connections are sometimes needed on discharge and suction piping. Pulsation in discharge and—to a lesser extent—suction lines, tends to vibrate piping. This effect is reduced by using bellows, large bends and laterals, instead of elbows and tees.

### **INSTRUMENTATION & INSTRUMENT CONNECTIONS**

Figure 6.23 shows the more useful locations for pressure and temperature gages, but does not show instrumentation for starting, stopping and unloading the compressors. Simple compressor control arrangements using pressure switches have long been used, but result in frequent starting and stopping of the compressor, causing unnecessary wear to equipment.

Automatic control using an unloading valve is superior: table 3.6 gives the working principles—see 3.2.2, under ‘Unloading’. Further information can be found in the ‘Compressor installation manual’ (Atlas-Copco). Unloading valves are allocated instrument numbers.

The air-pressure signals for unloading, starting, loading and stopping a compressor should be free from pulsations. It is best to take these signals from a connection on the receiver or a little downstream of it.

Details of construction of instrument connections are given in 6.7. Instrument branches should be braced to withstand transmission of line vibration.

### **ISOLATING VALVES FOR COMPRESSOR**

Compressors operating in parallel should be provided with isolating valves arranged so that any compressor in the group may be shut down or removed. An isolating valve at the discharge should be placed downstream of the pressure-relief valve and any bypass valve connection. The isolating valve at the suction should be upstream of the bypass valve connection. Isolating valves are not required for a single compressor installation.

### **PRESSURE-RELIEF VALVES**

Pressure-relief valves should be installed on interstage piping and on a discharge line from a compressor to the first downstream isolating valve. A pressure-relief valve may be vented to the suction line—see figure 6.23. Each pressure-relief valve should be able to discharge the full capacity of the compressor.

### **CHECK VALVE**

Unless supplied with (or integral with) a compressor, a check valve must be provided to prevent backflow of stored compressed air or other gas.

### **DISTRIBUTION OF COMPRESSED AIR**

Headers larger than 2-inch are often butt welded. Distribution lines are screwed and usually incorporate malleable-iron fittings, as explained in 2.5.1. Equipment used in distribution piping is described in 3.2.2.

A more efficient layout for compressed air lines is the ring main with auxiliary receivers placed as near as possible to points of heavy intermittent demand. The loop provides two-way air flow to any user.

### **COMPRESSED AIR USAGE**

The compressed air provided for use in plants is designated ‘instrument air’, ‘plant air’ or ‘process air’. Instrument air is cleaned and dried compressed air, used to prevent corrosion in some instruments. Plant air is compressed air but is usually neither cleaned nor dried, although most of the moisture and oil, etc., can be collected by a separator close to the compressor, especially if adequate cooling can take place. Plant air is used for cleaning, power tools, blowing out vessels, etc: if used for air-powered tools exclusively, some suspended oil is advantageous for lubrication, although filter/lube units are usually installed in the air line to the tool.

Process air is compressed air, cleaned and dried, which may be used in the process stream for oxidizing or agitation. The trend is to supply cleaned and dried air for both general process and instrument purposes. This avoids running separate lines for process and instrument air.

Process and instrument air for some applications requires to have an oil content less than 10 parts per million. As almost all oily contaminants are present as extremely small droplets (less than 1 micron in diameter) mechanical filtration may be ineffective; adsorption equipment can efficiently remove the oil.

## PIPING TO STEAM TURBINES

6.4

A turbine is a machine for deriving mechanical power (rotating shaft) from the expansion of a gas or vapor (usually air or steam, in industrial plants).

Steam turbines are used where there is a readily-available source of steam, and are also used to drive standby process pumps in critical service in the event of an electrical power failure, and emergency standby equipment such as firewater pumps and electric generators.

Figure 6.9 shows a schematic arrangement of piping for automatic operation. There are similarities between steam-turbine and pump and compressor piping. Their common requirements are:—

- (1) To limit loads on nozzles from weight of piping or from thermal movement
- (2) To provide access and overhead clearance
- (3) To prevent harmful material from entering the machine

### INLET (STEAM FEED)

6.4.1

In order to guard against damage to a steam turbine, protective piping arrangements such as those mentioned in table 6.4 are needed in the steam feed.

**PROTECTIVE PIPING FOR FEEDING STEAM TO TURBINE**

**TABLE 6.4**

| HAZARD TO TURBINE  | PROTECTIVE PIPING  |
|--|--|
| FOREIGN MATTER & WATER IN THE STEAM FEED                                     | DRIPLEG & STRAINER, or SEPARATOR, IN THE FEED LINE (See figure 6.9)  |
| EXCESSIVE PRESSURE IN STEAM FEED CAUSING OVER-FAST RUNNING OR CASING RUPTURE | PRESSURE RELIEF VALVE &/OR CONTROL VALVE IN THE FEED LINE            |
| THERMAL SHOCK, DUE TO TOO RAPID HEATING ON STARTUP                           | ORIFICE BYPASS TO FEED SMALL AMOUNT OF STEAM TO TURBINE AT ALL TIMES |

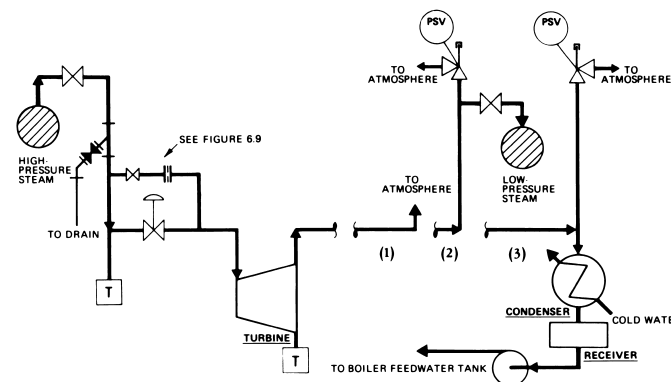
### EXHAUST (STEAM DISCHARGE)

6.4.2

Figure 6.25 shows three methods for dealing with the turbine's exhaust. Steam from an intermittently operated turbine may be run to waste and all that is required is a simple run of pipe to the nearest outside wall or up thru the roof. Exhausts should be well clear of the building and arranged so as not to be hazardous to personnel. The turbine discharge will include drops of water and oil from the turbine, which are best collected and run to drain. A device suitable for this purpose is a Swartwout 'exhaust head' shown in figure 6.26. Alternately, steam discharged from a continuously running turbine may be utilized elsewhere, in a lower-pressure system.

## TURBINE EXHAUST ARRANGEMENTS

**FIGURE 6.25**



### KEY :

- (1) Exhaust is discharged directly to atmosphere. Suitable for small turbine in intermittent use.
- (2) Exhaust is taken to a low-pressure header for use elsewhere. Suitable for continuously-operating turbine, to avoid wasting steam.
- (3) Exhaust is condensed to increase pressure drop across the turbine.

## BYPASS STEAM & OTHER PIPING FOR TURBINES

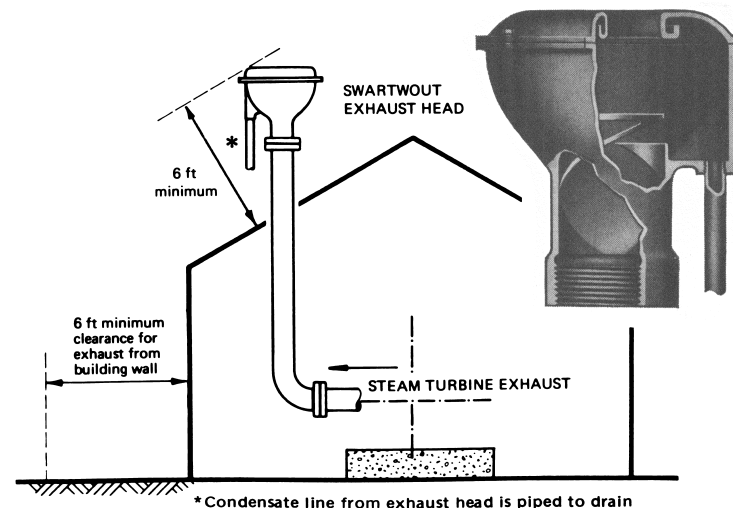
6.4.3

An orifice plate is used as a 'bleed' bypass to ensure that steam constantly passes thru the turbine. An orifice plate is used rather than a straight pipe, as a changeable constriction is needed. Alternately, the small amount of steam needed to keep the turbine warm can be admitted by a cracked-open valve in a bypass—a wasteful and uncertain practice.

A trap is fitted to the casing of the turbine to remove condensate. Piping is provided to supply seal liquid to the turbine's bearings—refer to 6.3.1, under 'Auxiliary, trim, or harness piping'.

### SWARTWOUT HEAD

**FIGURE 6.26**



## VESSEL CONNECTIONS

### 6.5.1

Vessel connections are often made with couplings (for smaller lines), flanged or welding nozzles, and pads fitted with studs, designed to mate with flanged piping. Nozzle outlets are also made by extrusion, to give a shape like that of the branch of a welding tee—this gives a good flow pattern, but is an expensive method usually reserved for such items as manifolds and dished heads. Weldolets, sockolets and thredolets are suitable for vessel connections and are available flat-based for dished heads, tanks, and large vessels.

Almost any type of connection may be made to open vessels or vessels vented to atmosphere, but for pressure vessels, the applicable design code will dictate requirements for connections (and possible reinforcement—see 2.11).

## PRESSURE VESSELS

With exceptions and limitations stated in section 8 of the ASME Boiler and Pressure Vessel Code, vessels subject to internal or external operating pressures not exceeding 15 PSI need not be considered to be pressure vessels. A vessel operating under full or partial vacuum and not subject to an external pressure greater than 15 PSI would not require Code certification.

## VESSEL DRAWING & REQUIRED NOZZLES

Preliminary piping layouts are made to determine a suitable nozzles arrangement. A sketch of the vessel showing all pertinent information is sent to the vessel fabricator, who then makes a detail drawing. The preliminary studies for pressure vessel piping layouts should indicate where pipe supports and platforms (if required) are to be located. In the event that the vessel has to be stress-relieved, the fabricator can provide clips or brackets—see 6.2.8, under ‘Welding pipe-support and platform brackets to vessels, etc.’

Figure 5.14 shows the type of drawing or sketch sent to a vessel fabricator.

## NOZZLES NEEDED ON VESSELS

- Nozzles needed on non-pressure vessels include: inlet, outlet, vent (gas or air), manhole, drain, overflow, agitator, temperature element, level instrument, and a ‘steamout’ connection, sometimes arranged tangentially, for cleaning the vessel
- Nozzles needed on pressure vessels include: inlet, outlet, manhole, drain, pressure relief, agitator, level gage, pressure gage, temperature element, vent, and for ‘steamout’, as above
- Check whether nozzles are required for an electric heater, coils for heating or cooling, or vessel jacket. A jacket requires a drain and vent
- Check special nozzle needs, such as for flush-bottom tank valves (see 3.1.9)

## PIPE FLEXIBLY TO NOZZLES

- Provide additional flexibility in lines to a vessel from pumps and other equipment mounted on a separate foundation (if liable to settle)
- Be cautious in making rigid straight connections between nozzles. Such connections may be acceptable if both items of equipment are on the same foundation, and are not subject to more than normal atmospheric temperature changes (see figure 6.1)

## NOZZLE LOADING

- Ensure that a nozzle can take the load imposed on it by connected piping—see 6.2.8, under ‘Supporting pipe at nozzles’. Manufacturers often can provide nozzle-loading data for their standard equipment
- Check all connections to ensure that stresses due to thermal movement, and shock pressures (‘kicks’) from opening pressure relief valves, etc., are safely handled

## FRACTIONATION COLUMN PIPING (OR TOWER PIPING)

### 6.5.2

As columns and their associated equipment take different forms, according to process needs, the following text gives a simplified explanation of column operation, and outlines basic design considerations.

## THE COLUMN’S JOB

A fractionation column is a type of still. A simple still starts with mixed liquids, such as alcohol and water produced by fermenting a grain, etc., and by boiling produces a distillate in which the concentration of alcohol is many times higher than in the feed. In the petroleum industry in particular, mixtures not of two but a great many components are dealt with. Crude oil is a typical feed for a fractionation column, and from it the column can form simultaneously several distillates such as wax distillate, gas oil, heating oil, naphtha and fuel gases. These fractions are termed ‘cuts’.

## COLUMN OPERATION

The feed is heated (in a ‘furnace’ or exchanger) before it enters the column. As the feed enters the column, quantities of vapor are given off by ‘flashing’, due to the release of pressure on the feed.

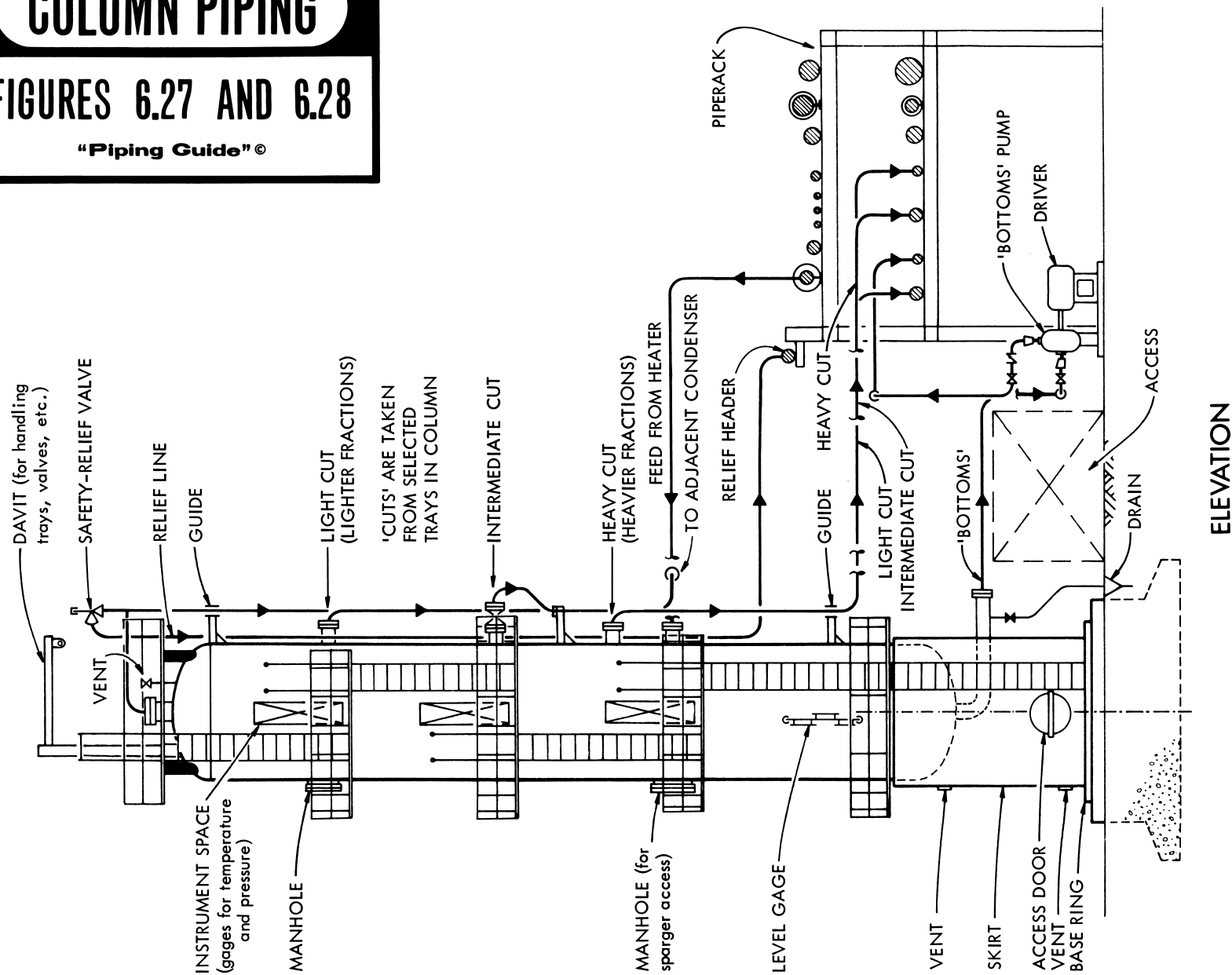
As the vapors rise up the column, they come into intimate contact with downflowing liquid—see figure 6.29. During this contact, some of the heavier components of the vapor are condensed, and some of the lighter components of the downflowing liquid are vaporized. This process is termed ‘refluxing’.

If the composition of the feed remains the same and the column is kept in steady operation, a temperature distribution establishes in the column. The temperature at any tray is the boiling point of the liquid on the tray. ‘Cuts’ are not taken from every tray. The P&ID shows cuts that are to be made, including alternatives—nozzles on selected trays are piped, and nozzles for alternate operation are provided with line blinds or valves.

# COLUMN PIPING

## FIGURES 6.27 AND 6.28

"Piping Guide" ©



ELEVATION

FIGURE 6.27

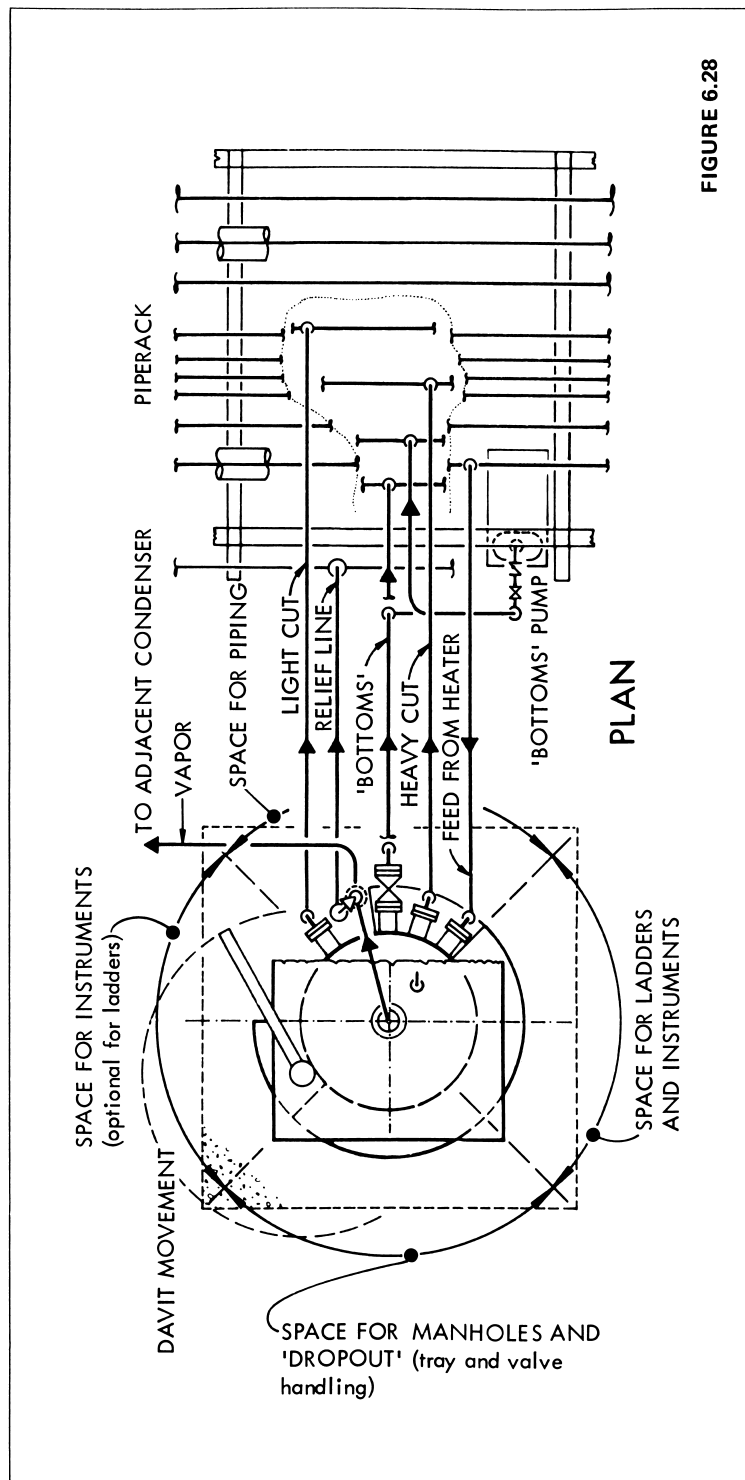
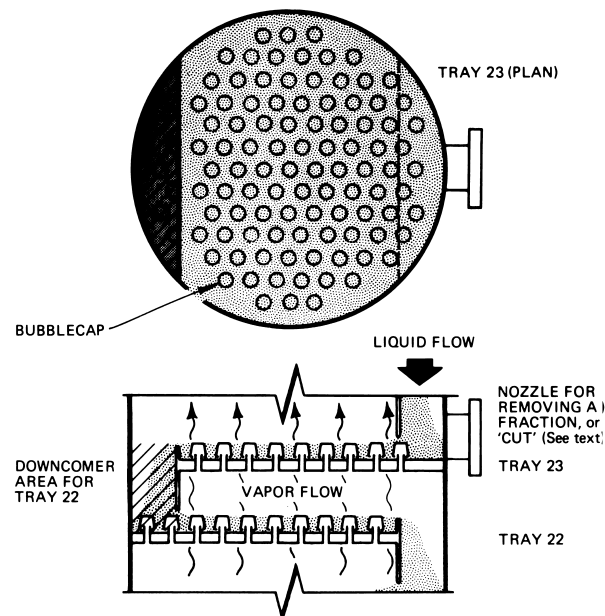


FIGURE 6.28

Trays are of various designs. Their purpose is to collect a certain amount of liquid but allow vapors to pass up thru them so that vapor and liquid come into contact. (Refer to figure 6.29, which shows simple bubblecap trays —many tray designs are available.)

TRAYS & BUBBLECAPS

FIGURE 6.29



To produce the required 'cuts', a column operates under steady temperature, feed, and product removal conditions. Starting from cold, products are collected after steady conditions are reached, and the column is then operated continuously.

All materials enter and leave the column thru pipes; therefor columns are located close to piperacks. Figures 6.27 and 6.28 show an arrangement. Products from the column are piped to collecting tanks (termed 'drums', 'accumulators', etc.) and held for further processing, or storage.

If the vapor from the top of the column is condensible, it is piped to a condenser to form a volatile liquid. The condenser may be mounted at grade, or sometimes on the side of the column.

Product from the top of the column may be gaseous at atmospheric pressure after cooling; if the product liquefies under moderate pressure, it may be stored pressurized in containers.

In addition to the condenser for the top product, a steam-heated heat exchanger, termed a 'reboiler', may be used to heat material drawn from a selected level in a column; the heated material is returned to the column. Reboilers are required for tall columns, and for columns operated at high temperatures, which are subject to appreciable loss of heat. Mounting the reboiler on the side of the column minimizes piping.

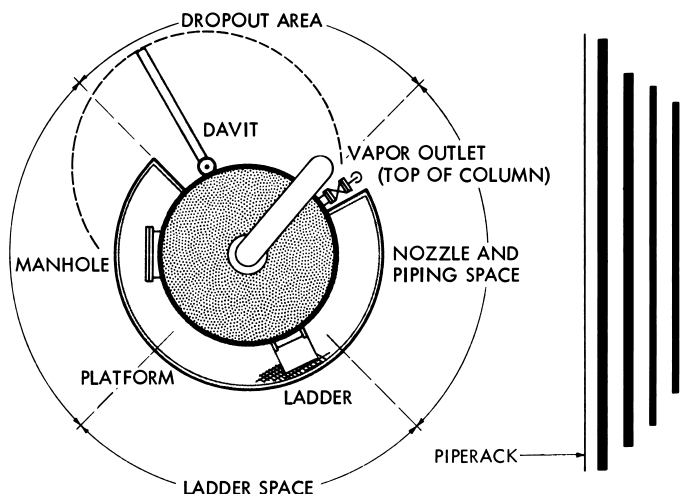
Material from the bottom of a column is termed 'bottoms', and must be pumped away (see figure 6.27)—this material consists of 'heavier' (higher molecular weight) liquids which either did not vaporize, or had condensed, plus any highly viscous material and solids in the feed.

## COLUMN ORIENTATION & REQUIREMENTS

Simultaneously with orientating nozzles and arranging piping to the column, the piping designer decides the positions of manholes, platforms, ladders, davit, and instruments.

### COLUMN ORIENTATION

FIGURE 6.30



Manholes are necessary to allow installation and removal of tray parts.

Platforms and ladders are required for personnel access to valves on nozzles, to manholes, and to column instruments.

A davit is needed to raise and lower column parts, and a dropout area has to be reserved.

### MANHOLES & NOZZLES

For a particular project or column, manholes are preferably of the same type. They should be located away from piping, and within range of the davit.

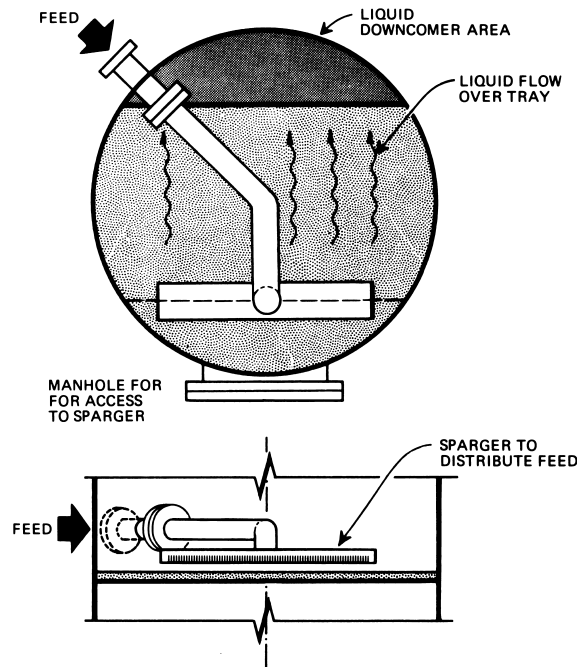
If required, manholes can be placed off the column centerlines (plan view).

The manhole serving the sparger unit (figure 6.31) should permit easy removal of the unit, which may be angled to place the feed connection in a desired position.

The portions of the column wall available for nozzles are determined by the orientation and type of tray—see figure 6.29. Elevations of nozzles are taken from the column data sheet (normally in the form of a vessel drawing).

### SPARGER UNIT

FIGURE 6.31



If the cuts are to be taken either from even-numbered trays, or from odd-numbered trays, all nozzles can be located on one side of the column, facing the piperack. If cuts are to come from both even- and odd-numbered trays, it will almost certainly be impossible to arrange all nozzles toward the piperack. (See 'Arranging column piping', this section.)

### PLATFORMS & LADDERS

Platforms are required under manholes, valves at nozzles, level gages, controllers if any, and pressure relief valves. Columns may be grouped and sometimes interconnecting platforms between columns are used. Individual platforms for a column are usually shaped as circular segments, as shown in figure 6.30. A platform is required at the top of the column, for operating a davit, a vent on shutdown, and for access to the safety-relief valve. This top platform is often rectangular.

Usual practice is to provide a separate ladder to go from grade past the lowest platform. Ladders are arranged so that the operator steps sideways onto the platforms.

Ladder length is usually restricted to 30 ft between landings. Some States allow 40 ft (check local codes). If operating platforms are further apart than the maximum permissible ladder height, a small intermediate platform is provided.

Ladders and cages should conform to the company standard and satisfy the requirements of the US Department of Labor (OSHA), part 1910.(D).

## DAVIT

Referring to figure 6.30, the davit should be located at the top of the column so that it can lower and raise tray parts, piping, valves, etc., between the platforms and the dropout area at grade.

## ARRANGING COLUMN PIPING

To achieve simplicity and good arrangement, some trial-and-error working is necessary. Columns are major pieces of equipment, and their piping needs take precedence over other piping.

As lines from nozzles on the column are run down the length of the column, it is logical to start arranging downcomers from the top and proceed down the column. A lower nozzle may need priority, but usually piping can be arranged more efficiently if the space requirements of piping coming from above are already established.

Sometimes tray spacing is increased slightly to permit installation of manholes. It may be possible to rotate trays within limits, to overcome a difficulty in arranging column piping. Such changes in tray spacing and arrangement must be sanctioned by the process engineer and vessel designer.

- Allocate space for vertical lines from lower nozzles, avoiding running these lines thru platforms if possible
- Lines from the tops of columns tend to be larger than others. Allocate space for them first, keeping the lines about 12 inches from the platforms and the wall of the column—this makes supporting easier, and permits access to valves, instruments, etc.
- Allocate space for access (manholes, ladders) clear of piping—especially clear of vertical lines
- Provide a clear space for lowering equipment from the top of a column (for maintenance, etc.)
- Provide access for mobile lifting equipment to condenser and reboiler
- Provide clearance to grade (approximately 8ft) under the suction line, from the column to the bottoms pump
- Arrange vent(s) in the skirt of the column
- Ensure that no low point occurs in the line conveying 'bottoms' to the suction port of the bottoms pump, in order to avoid blocking of this line due to cooling, etc.

## INFORMATION NEEDED TO ARRANGE THE COLUMN PIPING

- Plot plan showing space available for column location, and details of equipment which is to connect to the column
- P&ID for nozzle connections, NPSH of bottoms pump, instrumentation, line blinds, relief valves, etc.
- Column data sheets and sketch of column showing elevations of nozzles

- Line designation sheets, to obtain operating temperatures of lines for calculating thermal movement
- Details of trays and other internal parts of the column
- Restrictions on the heights of ladders
- Operational requirements for the plant

## BOTTOMS PUMP & ELEVATION OF COLUMN

The elevation of a column is set primarily by the NPSH required by the bottoms pump, the access required under the suction line to the bottoms pump, and by requirements for a thermosyphon reboiler, if used.

## VALVES

Valves and blinds which serve the tower should be positioned directly on nozzles, for economy. It is desirable to arrange other valves so that lines are self-draining.

Platforms should be located to give access to large valves. Small valves may be located at the ends of platforms. Control valves should be accessible from operating platforms or from grade.

The pressure-relief valve for the relief line should be placed at the highest point in the line, and should be accessible from the top platform.

Valves should not be located within the skirt of the column.

## INSTRUMENTS & CONNECTIONS

Temperature connections should be located to communicate with liquids in the trays, and pressure connections with the vapor spaces below the trays. Access to isolated gages can be provided by ladder.

Gages, and gage and level glasses, must be visible when operating valves, and be accessible for maintenance.

Gages and other instruments should be located clear of manholes and accessways to ladders and platforms. If necessary, temperature and pressure gages may be located for reading from ladders. Locating instruments at one end of a circular platform may allow a narrower platform.

## THERMAL INSULATION

Thermal insulation of the exterior of a column may be required in order to reduce heat loss to the atmosphere. Insulation may be inadequate to maintain the required temperature distribution; in these circumstances, a reboiler is used. Thermal insulation is discussed in 6.8.1.

## FOUNDATION FOR COLUMN

The base ring of a column's skirt is attached to a reinforced-concrete construction. The lower part of this construction, termed the 'foundation', is below grade, and is square in plan view; the upper part, termed the 'base', to which the base ring is attached, is usually octagonal and projects above grade approximately 6 inches.

## PIPING FOR HEAT EXCHANGERS

### 6.6

Heat exchangers are discussed in 3.3.5.

### DATA NEEDED TO PLAN EXCHANGER PIPING

#### 6.6.1

Preliminary exchanger information should be given early to the piping group, so that piping studies can be made with special reference to orientation of nozzles. Before arranging heat-exchanger piping, the following information is needed:

**PROCESS FLOW DIAGRAM** This will show the fluids that are to be handled by the exchangers, and will state their flow rates, temperatures and pressures.

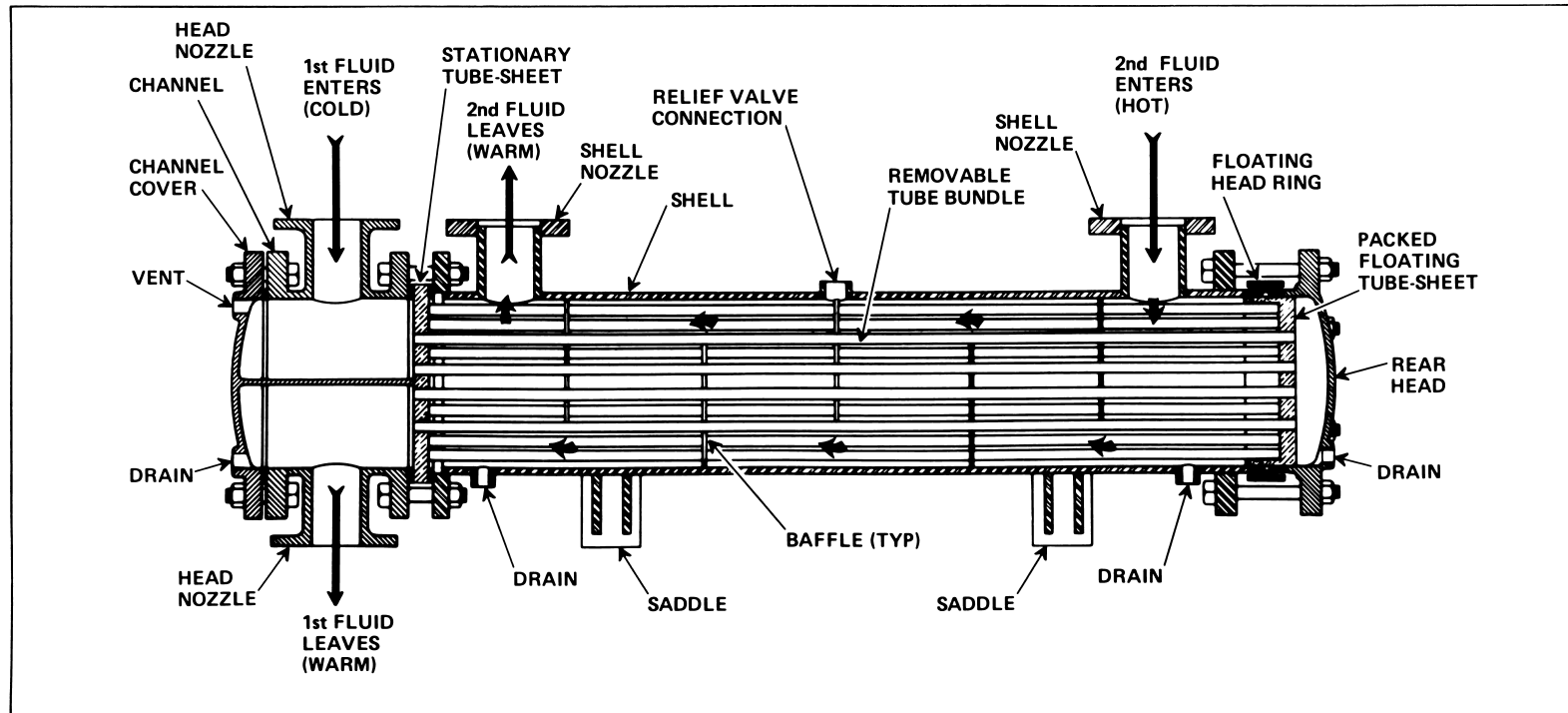
**EXCHANGER DATA SHEETS** One of these sheets is compiled for each exchanger design by the project group. The piping group provides nozzle orientation sketches (resulting from the piping studies). The data sheet informs the manufacturer or vendor of the exchanger concerning performance and code stamp requirements, materials, and possible dimensional limitations.

### TEMA CODING FOR EXCHANGER TYPE

The Tubular Exchangers Manufacturers Association (TEMA) has devised a method for designating exchanger types, using a letter coding. The exchanger shown in figure 6.32 would have the basic designation AEW. See chart H-1.

### SHELL-AND-TUBE HEAT EXCHANGER WITH REMOVABLE TUBE BUNDLE

FIGURE 6.32



## DESIGN POINTERS

### 6.6.2

#### Engineering Notes:

- Provide the shell with a pressure-relieving device to protect against excessive shell-side pressure in the event of internal failure
- Put fouling and/or corrosive fluids inside the tubes as these are (except U-type) easily cleaned, and cheaper to replace than the shell
- Put the hotter fluid in the tubes to reduce heat loss to the surroundings
- However, if steam is used to heat a fluid in an exchanger, passing the steam thru the shell has advantages: for example, condensate is far easier to handle shellside. Insulation of the shell is normally required to protect personnel, and to reduce the rates of condensate formation and heat loss
- Pass refrigerant or cooling liquid thru the tubes, if the exchanger is not insulated, for economic operation
- If heat transfer is between two liquids, a countercurrent flow pattern will usually give greater overall heat transfer than a paralleled flow pattern, other factors being the same
- Orientate single-tube spiral, helical and U-tube exchangers (with steam fed thru the tube) to permit outflow of condensate

### Nozzle Positions:

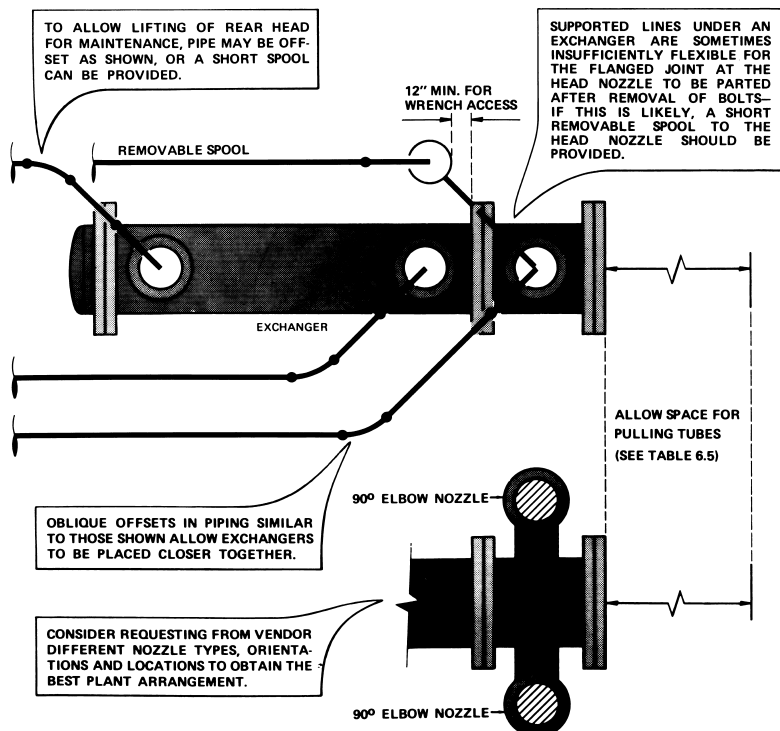
- Arrange nozzles to suit the best piping and plant layout. Nozzles may be positioned tangentially or on elbows, as well as on vertical or horizontal centerlines (as usually offered at first by vendors). Although a tangential or elbowed nozzle is more expensive, it may permit economies in piping multiple heat exchangers
- Make condensing vapor the descending stream
- Make vaporizing fluid the ascending stream

### Locating Exchangers:

- Position exchangers so that piping is as direct and simple as possible. To achieve this, consider alternatives, such as reversing flows, arranging exchangers side-by-side or stacking them, to minimize piping
- Elevate an exchanger to allow piping to the exchanger's nozzles to be arranged above grade or floor level, unless piping is to be brought up thru a floor or from a trench
- Exchangers are sometimes of necessity mounted on structures, process columns and other equipment. Special arrangements for maintenance and tube handling will be required

### PIPING TO NOZZLES OF HEAT EXCHANGERS

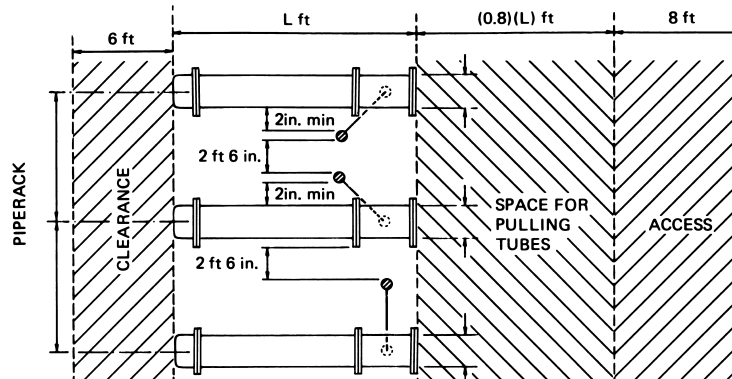
FIGURE 6.33



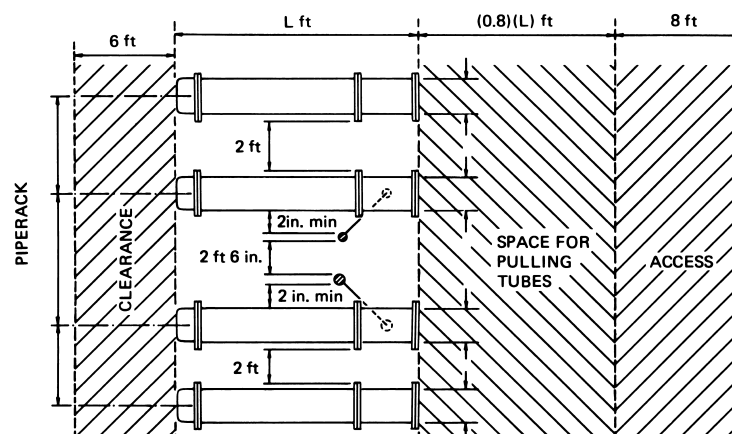
### MINIMUM SPACING & CLEARANCES FOR MULTIPLE HEAT EXCHANGERS

TABLE 6.5

(a) Exchangers arranged with 2 ft 6 in. operating space between piping



(b) Exchangers arranged with 2 ft 0 in. maintenance space between paired units and 2 ft 6 in. operating space between piping



| NOTES | (1) Show outlines of exchanger supports or foundations before arranging piping   |
|-------|--|
|       | (2) Add to clearances shown, thicknesses of insulation for exchanger shells and connected piping   |
|       | (3) Provide additional clearance to the 2'-6" operating space if valve handwheels and valve stems, etc., protrude, depending on piping arrangement |

### Operating and Maintenance Requirements:

- Access to operating valves and instruments (on one side only suffices)
- Operating space for any davit, monorail or crane, etc., both for movement and to set loads down
- Access to exchanger — space is needed for tube-bundle removal, for cleaning, and around the exchanger's bolted ends (channelcover and rear head) and the bolted channel-to-shell closure
- Access for tube bundle removal is often given on manufacturers' drawings, and is usually about  $1\frac{1}{2}$  times the bundle length. 15 to 20 ft clearance should be allocated from the outer side of the last exchanger in a row for mobile lifting equipment access and tube handling

# INSTRUMENT CONNECTIONS

INCH SIZES FOR VALVES, FITTINGS & PIPE ARE NOMINAL AND SHOWN ON DRAWINGS AS NOMINAL PIPE SIZES. FOR EXAMPLE, PIPE 4" IS SHOWN ON DRAWINGS AS PIPE NPS 4

## CHART 6.2

| NOMINAL LINE SIZE       |  | in.  | 1/2 | 3/4 thru 1 1/2 | 2  | 2 1/2 | 3  | 4   | 6 and larger   |
|-------------------------|--|--|-----|----------------|----|-------|----|-----|----------------|
|                         |  | mm   | 15  | 20 thru 40     | 50 | 65    | 80 | 100 | 150 and larger |
| TEMPERATURE CONNECTIONS | Threaded Thermowells in Straight Runs                        |  |     |                |    |       |    |     |                |
|                         | Threaded Thermowells in Elbows                               |  |     |                |    |       |    |     |                |
|                         | Flanged Thermowells in Straight Runs                         |  |     |                |    |       |    |     |                |
|                         | Flanged Thermowells in Elbows                                |  |     |                |    |       |    |     |                |
| PRESSURE CONNECTIONS    | Screwed Connections for Pressure Instruments                 |  |     |                |    |       |    |     |                |
|                         | Socket-welded Connections for Pressure Instruments           |  |     |                |    |       |    |     |                |
|                         | Diaphragm Isolated Instrument Connections (for welded lines) |  |     |                |    |       |    |     |                |
|                         |  | <p>ALTERNATE BRANCH CONNECTIONS SUITABLE FOR INSTRUMENTS ARE DESCRIBED IN 2.3.2 (FOR BUTT-WELDED SYSTEMS), 2.4.2 (FOR SOCKET WELDED SYSTEMS) AND IN 2.5.2 (FOR SCREWED SYSTEMS).</p> |     |                |    |       |    |     |                |

ALTERNATE BRANCH CONNECTIONS SUITABLE FOR INSTRUMENTS ARE DESCRIBED IN 2.3.2 (FOR BUTT-WELDED SYSTEMS), 2.4.2 (FOR SOCKET WELDED SYSTEMS) AND IN 2.5.2 (FOR SCREWED SYSTEMS)

## INSTRUMENT CONNECTIONS

6.7

### PRIMARY CONNECTIONS TO LINES & EQUIPMENT

6.7.1

Connections will usually be specified by company standards or by the specifications for the project. If no specification exists, full- and half-couplings, swaged nipples, thredolets, nipolets and elbolets, etc., may be used. Chart 6.2 illustrates instrument connections used for lines of various sizes. The fittings shown in chart 6.2 are described in chapter 2. Orifice flange connections are discussed in 6.7.5.

### CHOOSING THE CONNECTION

6.7.2

The choice of instrument connection will depend on the conveyed fluid and sometimes on the required penetration of the element into the vessel or pipe. Instrument connections should be designed so that servicing or replacement of instruments can be carried out without interrupting the process. Valves are needed to isolate gages for maintenance during plant operation and during hydrostatic testing of the piping system. These valves are shown in chart 6.2 and are referred to as 'root' or 'primary' valves.

### TEMPERATURE & PRESSURE CONNECTIONS

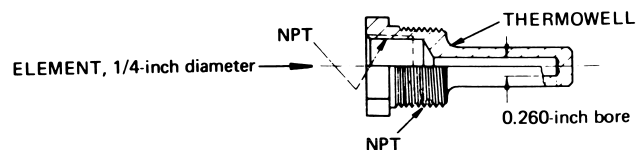
6.7.3

Chart 6.2 illustrates various methods for making temperature and pressure connections. At the bottom of chart 6.2 a method of connecting a diaphragm flange assembly (diaphragm isolator) is shown. Corrosive, abrasive or viscous fluid in the process line presses on one side of the flexible diaphragm, and the neutral fluid (glycol, etc.) on the other side transmits the pressure.

If the conveyed fluid is hazardous or under high pressure a branch fitted with a bleed valve is inserted between the gage and its isolating valve, to relieve pressure and/or drain the liquid before servicing the gage. The bleed valve can also be used to sample, or for adding a comparison gage.

- Position connections for instruments so that the instruments can be seen when operating associated valves, etc.
- Pressure connections for vessels containing liquids are usually best located above liquid level
- A temperature-measuring element is inserted into a metal housing termed a 'thermowell'. Place thermowells so that they are in contact with the fluid—an elbow is a good location, due to the increased turbulence

### THERMOWELL CONSTRUCTION (EXAMPLE)



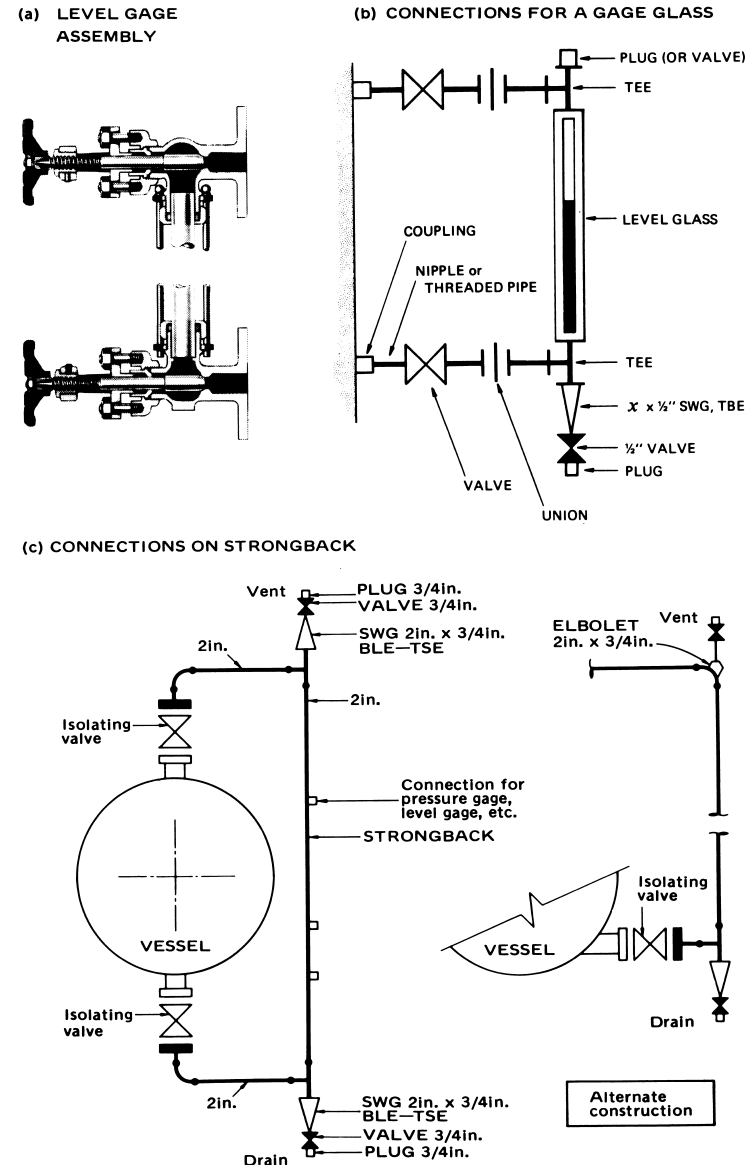
## LEVEL GAGE CONNECTIONS (TYPICAL)

6.7.4

- Locate a liquid level controller (float type, for example) clear of any turbulence from nozzles
- More than one level gage, level switch, etc., may be required on a vessel: consider installing a 'strongback' to a horizontal vessel on which instrument connections have to be made—see figure 6.34(c)

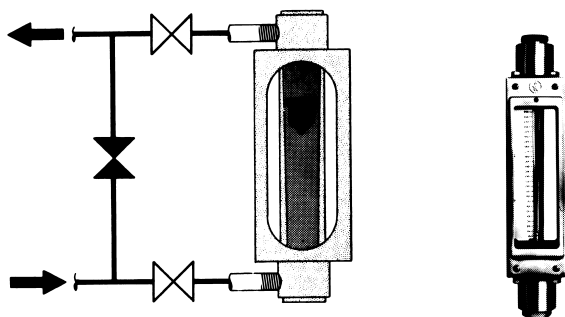
### LEVEL-GAGE CONNECTIONS

FIGURE 6.34

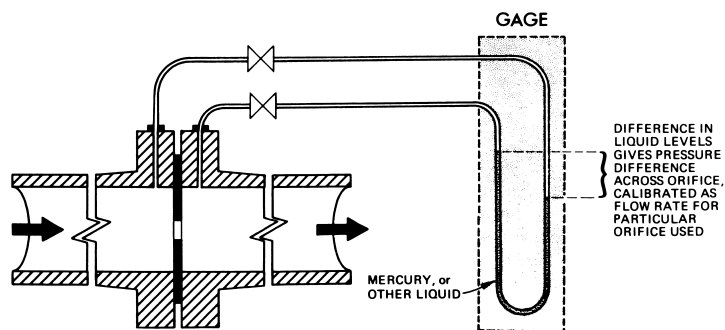


**ROTAMETER CONNECTIONS**

A rotameter consists of a transparent tube with tapered and calibrated bore, arranged vertically, wide end up, supported in a casing or framework with end connections. The instrument should be connected so that flow enters at the lower end and leaves at the top. A ball or spinner rides on the rising gas or liquid inside the tapered tube — the greater the flow rate, the higher the ball or spinner rides. Isolating valves and a bypass should be provided, as in figure 6.35

**ROTAMETER****FIGURE 6.35****(a) PIPING TO ROTAMETER****(b) INDUSTRIAL ROTAMETER****ORIFICE PLATE ASSEMBLY**

An 'orifice plate' is a flat disc with a precisely-made hole at its center. It offers a well-defined obstruction to flow when inserted in a line—see figure 6.36. The resistance of the orifice sets up a pressure difference in the fluid either side of the plate, which can be used to measure the rate of flow.

**ORIFICE PLATE ASSEMBLY & GAGE (MANOMETER)****FIGURE 6.36**

The orifice plate is held between special flanges having 'orifice taps'—these are tapped holes made in the flange rims, to which tubing and a pressure gage can be connected, as in figure 6.36. A pressure gage may be termed a 'manometer'.

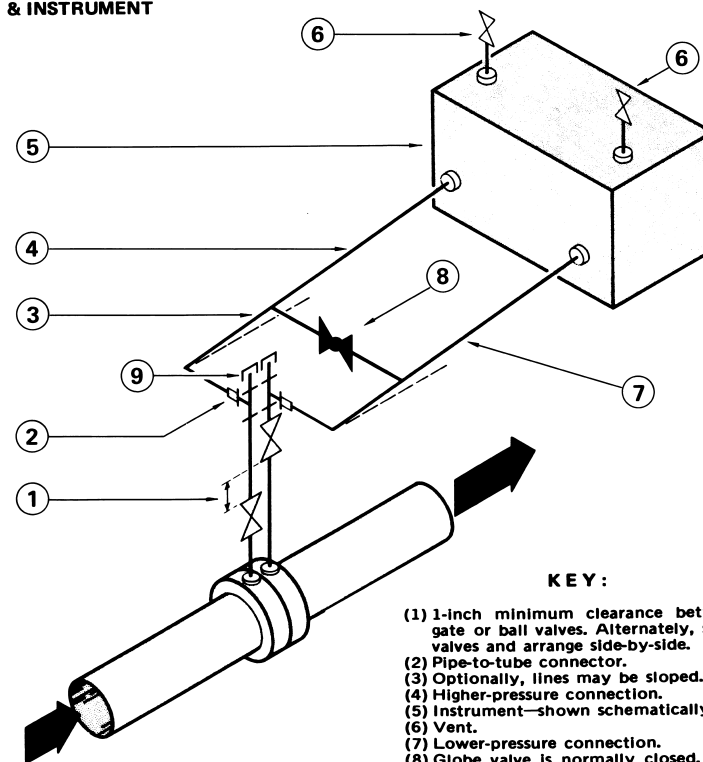
Manometers for use with orifice plate assemblies are calibrated in terms of differential pressure by the manufacturer. The meter run (that is, the piping in which the orifice plate is to be installed) must correspond with the piping used to calibrate the orifice plate—the readings will be in error if there is very much variation in these two piping arrangements.

Sometimes the orifice assembly includes adjacent piping, ready for welding in place. Otherwise, lengths of straight pipe, free from welds, branches or obstruction, should be provided upstream and downstream of the orifice assembly.

Table 6.6 shows lengths of straight pipe required upstream and downstream of orifice flanges (for different piping arrangements) to sufficiently reduce turbulence in liquids for reliable measurement.

**PIPING TO FLANGE TAPS**

Figure 6.37 shows a suitable tapping and valving arrangement at orifice flange taps. In horizontal runs, the taps are located at the tops of the flanges in gas, steam and vapor lines. An approximately horizontal position avoids vapor locks in liquid lines. Taps should not be pointed downward, as sediment may collect in pipes and tubes.

**CONNECTIONS TO ORIFICE FLANGES & INSTRUMENT****FIGURE 6.37**

- KEY:**
- (1) 1-inch minimum clearance between gate or ball valves. Alternately, splay valves and arrange side-by-side.
  - (2) Pipe-to-tube connector.
  - (3) Optionally, lines may be sloped.
  - (4) Higher-pressure connection.
  - (5) Instrument—shown schematically.
  - (6) Vent.
  - (7) Lower-pressure connection.
  - (8) Globe valve is normally closed. It is opened only for 'zero checking' the instrument.
  - (9) Cap. Removed for 'rodding out'.

## STRAIGHT PIPE RUN TO THE ORIFICE

The arrangement of orifice plate assemblies should be made in consultation with the instrument engineer. Usually, it is preferred to locate orifice plate assemblies in horizontal lines.

Flow conditions consistent with those used to calibrate the instrument are ensured by providing adequately long straight sections of pipe upstream and downstream of the orifice. Table 6.6 gives lengths that have been found satisfactory for liquids.

**STRAIGHT PIPE UPSTREAM & DOWNSTREAM OF ORIFICE ASSEMBLY**

**TABLE 6.6**

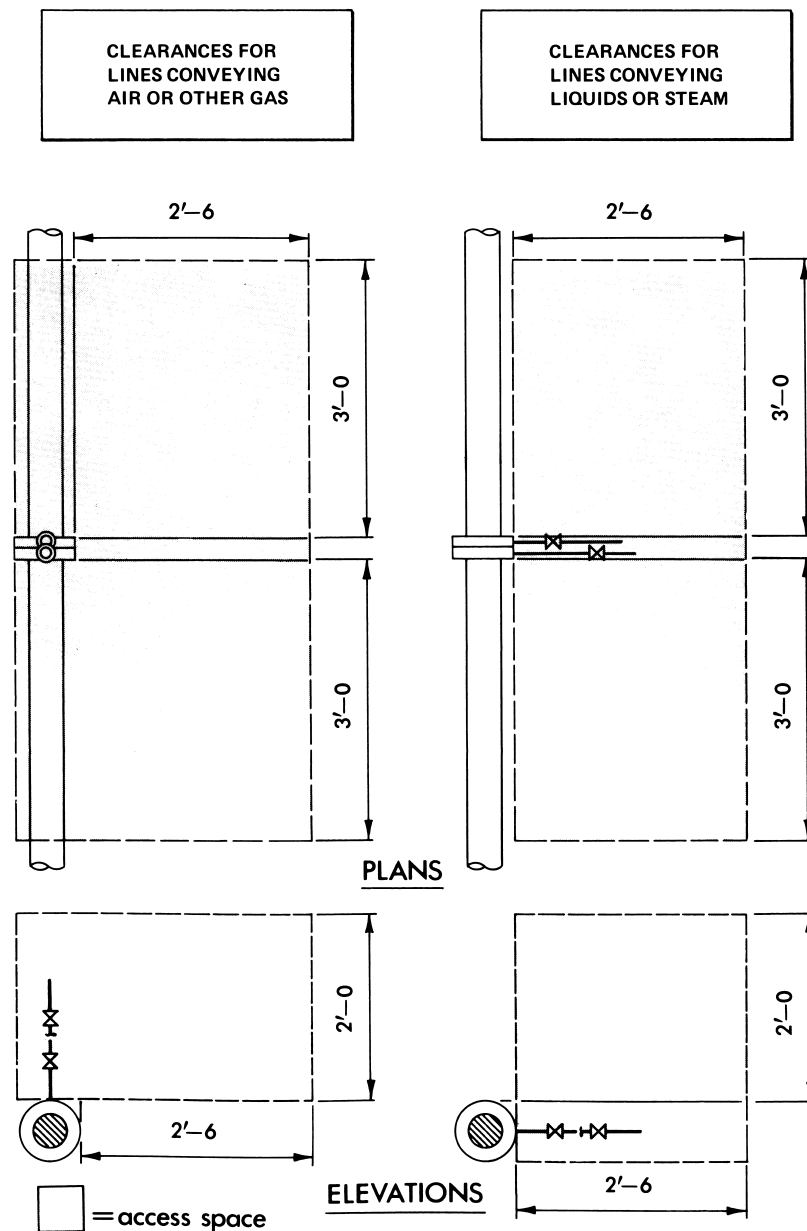
| KEY NUMBER OF PIPING ARRANGEMENT               | U=UPSTREAM<br>D=DOWNSTREAM | RATIO OF INTERNAL DIAMETERS OF ORIFICE PLATE AND PIPE  |       |       |       |       |         |
|--|----------------------------|--|-------|-------|-------|-------|---------|
|  |                            | 1 : 8  | 1 : 4 | 3 : 8 | 1 : 2 | 5 : 8 | 3 : 4 * |
|  |                            | MINIMUM RUNS OF STRAIGHT PIPE REQUIRED UPSTREAM AND DOWNSTREAM OF ORIFICE, IN PIPE DIAMETERS (NPS) |       |       |       |       |         |
| 1  | U                          | 6  | 6     | 6     | 6½    | 10    | 17      |
|  | D                          | 2½   | 3     | 3¾    | 3¾    | 4     | 4½      |
| 2  | U                          | 13   | 13    | 13    | 15    | 20    | 31      |
|  | D                          | 2½   | 3     | 3¾    | 3¾    | 4     | 4½      |
| 3  | U                          | 6  | 6     | 6     | 7½    | 10½   | 13½     |
|  | D                          | 2½   | 3     | 3¾    | 3¾    | 4     | 4½      |
| 4  | U                          | 5  | 5     | 5½    | 6½    | 8½    | 11      |
|  | D                          | 2½   | 3     | 3¾    | 3¾    | 4     | 4½      |
| 5  | U                          | 16½  | 18½   | 21½   | 25    | 32    | 44      |
|  | D                          | 2½   | 3     | 3¾    | 3¾    | 4     | 4½      |
| * USE THIS COLUMN FOR PRELIMINARY PLANNING     |                            |  |       |       |       |       |         |
| KEY: PIPING ARRANGEMENTS FOR ABOVE RUN LENGTHS |                            |  |       |       |       |       |         |
| 1  | Ell or Tee                 |  |       |       |       |       |         |
| 2  | Two 90° Ells               |  |       |       |       |       |         |
| 3  | Reducer or Increaser       |  |       |       |       |       |         |
| 4  | Gate Valve                 |  |       |       |       |       |         |
| 5  | Globe Valve                |  |       |       |       |       |         |

## CLEARANCES

Clear space should be left around an orifice assembly. Figure 6.38 shows minimum clearances required for mounting instruments, seal pots, etc., and for maintenance.

**CLEARANCES TO ORIFICE ASSEMBLIES**

**FIGURE 6.38**



## KEEPING PROCESS MATERIAL AT THE RIGHT TEMPERATURE

6.8

To ensure continuity of plant operations it is necessary to maintain some process, service and utility lines within a desired temperature range in order to keep materials in a fluid state, to prevent degradation, and to prevent damage caused by liquids freezing in cold conditions. Piping can be kept warm by insulation, or by applying heat to the insulated piping—this is 'jacketing' or 'tracing', as discussed in 6.8.2 and 6.8.3.

### THERMAL INSULATION

6.8.1

#### INSULATION

'Insulation' is covering material having poor thermal conductivity applied externally to pipe and vessels, and is used: (1) To retain heat in a pipe or vessel so as to maintain process temperature or prevent freezing. (2) To minimize transfer of heat from the surroundings into the line or vessel. (3) To safeguard personnel from hot lines. The choice of insulation is normally included with the piping specification. The method of showing insulation on piping drawings is included in chart 5.7.

Installed insulation normally consists of three parts: (1) The thermal insulating material. (2) The protective covering for it. (3) The metal banding to fasten the covering. Most insulating materials are supplied in formed pieces to fit elbows, etc. Formed coverings are also available. Additionally, it is customary to paint the installed insulation, and to weatherproof it before painting, if for external use.

The principal thermal insulating materials and their accepted approximate maximum line temperatures, where temperature cycling (repetitive heating and cooling periods) occurs are: asbestos (1200 F), calcium silicate (1200 F), cellular glass [foamglas] (800 F), cellular silica (1600 F), diatomaceous silica plus asbestos (1600 F), mineral fiber (250–1200 F, depending on type), mineral wool (1200 F), magnesia (600 F), and polyurethane foam (250 F). Certain foamed plastics have a very low conductivity, and are suitable for insulating lines as cold as –400 F. Rock cork [bonded mineral fiber] is satisfactory down to –250 F, and mineral wool down to –150 F.

#### HOW THICK SHOULD INSULATION BE ?

Most insulation in a plant will not exceed 2 inches in thickness. A rough guide to insulation thicknesses of the more common materials required on pipe to 8-inch size is:

GUIDE TO INSULATION THICKNESS

TABLE 6.7

| APPLICATION            | TYPICAL INSULATING MATERIAL  | USUAL THICKNESS OF INSULATION |
|------------------------|------------------------------|-------------------------------|
| Hot Lines (to 500 F)   | Asbestos, Silicate, Magnesia | 1 to 2 inches                 |
| Cold Lines (to –150 F) | Mineral Wool                 | 1 to 3 inches                 |
| Personnel Protection   | Asbestos, Silicate, Magnesia | 1 inch                        |

For personnel protection insulation should be provided up to a height of about 8 ft above operating floor level. Alternately, wire mesh guards can be provided. The following more detailed table gives insulation thickness for heat conservation, based on 85% magnesia to 600 F, and calcium silicate above 600 F.

INSULATION REQUIRED FOR PIPE AT VARIOUS TEMPERATURES

TABLE 6.8

| NOMINAL PIPE SIZE<br>(in.) | INCHES THICKNESS OF INSULATION FOR STATED TEMPERATURE RANGE |         |         |         |          |           |
|----------------------------|---|---------|---------|---------|----------|-----------|
|                            | Temperature Range in Degrees Fahrenheit                     |         |         |         |          |           |
|                            | below 400   | 400–549 | 550–699 | 700–899 | 900–1049 | 1050–1200 |
| to 1                       | 1   | 1       | 1.5     | 2       | 2        | 2.5       |
| 1.5                        | 1   | 1.5     | 1.5     | 2       | 2        | 2.5       |
| 2                          | 1   | 1.5     | 1.5     | 2       | 2.5      | 3         |
| 3                          | 1   | 1.5     | 1.5     | 2.5     | 2.5      | 3         |
| 4                          | 1   | 1.5     | 1.5     | 2.5     | 2.5      | 3.5       |
| 6                          | 1   | 1.5     | 1.5     | 2.5     | 2.5      | 3.5       |
| 8                          | 1.5   | 1.5     | 2       | 2.5     | 3        | 3.5       |
| 10                         | 1.5   | 1.5     | 2       | 2.5     | 3        | 4         |
| 12                         | 1.5   | 2       | 2       | 2.5     | 3        | 4         |
| 14                         | 1.5   | 2       | 2       | 2.5     | 3        | 4         |
| 16                         | 2   | 2       | 2       | 3       | 3.5      | 4         |
| 18                         | 2   | 2       | 2       | 3       | 3.5      | 4         |
| 20                         | 2   | 2       | 2       | 3       | 3.5      | 4         |
| 24                         | 2   | 2       | 2       | 3       | 3.5      | 4         |

### JACKETING & TRACING

6.8.2

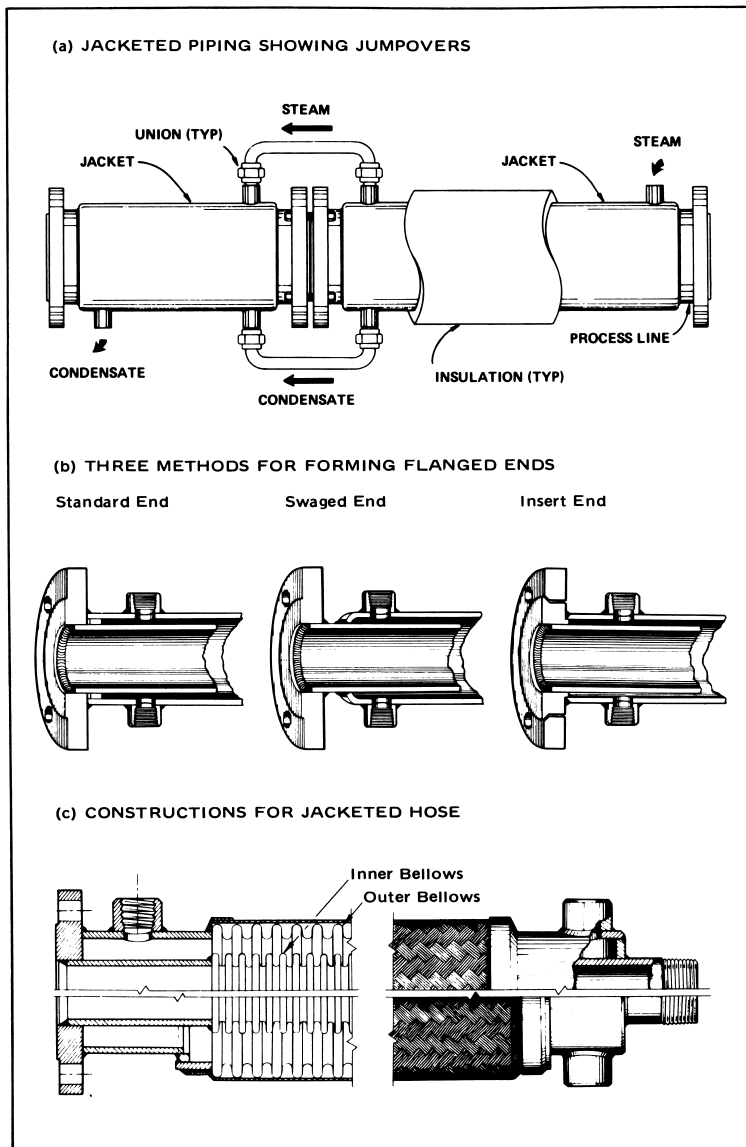
The common methods by which temperatures are maintained, other than by simple insulation, are jacketing and tracing (with insulation).

#### JACKETING

Usually, 'jacketing' refers to double-walled construction of pipe, valves, vessels, hose, etc., designed so that a hot or cold fluid can circulate in the cavity between the walls. Heating media include water, oils, steam, or proprietary high-boiling-point fluids which can be circulated at low pressure, such as Dowtherm or Therminol. Cooling media include water, water mixtures and various alcohols.

Jacketed pipe can be made by the piping fabricator, but an engineered system bought from a specialist manufacturer would be a more reliable choice. The jumpover lines connecting adjacent jackets, thru which the heating or cooling medium flows are factory-made by the specialist manufacturer with less joints than those made on-site, where as many as nine screwed joints may be necessary to make one jumpover. Details of the range of fittings, valves and equipment available and methods of construction for steel jacketed piping systems can be found in Parks-Cramer's and other catalogs.

Another type of jacketing is 'Platecoil' (Tranter Manufacturing Inc.) which is a name given to heat transfer units fabricated from embossed metal sheets, joined together to form internal channeling thru which the heating (or cooling) fluid is passed. The term 'jacketing' is also applied to electric heating pads or mantles which are formed to fit equipment. It also sometimes refers to the spiral winding of electric tracing and fluid tracing lines around pipes, vessels, etc.



## TRACING

External 'tracing' consists in running tubing filled with a hot fluid (usually steam), or electric heating cables, in contact with the outer surface of the pipe to be kept warm. The tubing or cables may be run parallel to the pipe or wound spirally around it. The pipe and tracer(s) are encased in thermal insulation.

An alternative, now little used due to sealing and cleaning problems, is internal tracing by means of tubing fitted inside the line to be heated. An internal tracer is termed a 'gutline'.

'Unitrace' (Aluminum Company of America) is an integral product and tracer pipe extruded in aluminum, which gives excellent heat transfer. The system uses flanges and jumpover fittings similar to those used for jacketed systems to connect adjacent traced sections of the lines.

Electric tracing allows close control of temperature, and can provide a wider range of temperatures than steam heating.

## GETTING HEAT TO THE PROCESS LINE (USING STEAM)

If the process line temperature has to approach that of the available steam, jacketing gives the best results. Barton and Williams have stated [4] that the cheaper method of welding steam tracers directly to the process lines has proven adequate. In this unusual method, the welding is 'tack' or continuous depending on how much heat is required to be transferred thru the weld.

A greater rate of heat transfer may be achieved by using two (seldom more) parallel tracers. Sometimes a single tracer is spirally wound about the pipe, but spiral winding should be restricted to vertical lines where condensate can drain by gravity. If the temperature of the conveyed fluid has to be closely maintained, winding the tracer is too inaccurate—but it is a suitable method for getting increased heating in non-critical applications.

To improve heat transfer between the tracer and pipe, they may either be pressed into contact by banding or wiring them together at frequent (1 to 4 ft) intervals, or a heat-conducting cement such as 'Thermon' can be applied. Unless used to anchor the tracer, banding is normally applied sufficiently loosely to permit the tracer to expand.

Hot spots occur at the bands. If this is undesirable for a product line, a thin piece of asbestos may be inserted between tracer and line.

## CHOOSING THE SYSTEM

There are advantages and disadvantages with the various systems. Piping which is to be externally traced can be planned with little concern for the tracing.

Fluid-jacketed systems are flanged, and last-minute changes could result in delays. Jacketing offers superior heat transfer and should be seriously considered for product lines, especially for those conveying viscous liquids and material which may solidify, whereas service lines usually just need to be kept from freezing and tracing is quite adequate for them. If process material has to be kept cold in the line, refrigerant-jacketed systems are the only practicable choice.

For process lines, all systems should be evaluated on the criteria of heat distribution, initial cost and long-term operating and maintenance costs before a decision can be made.

## WHERE TRACING & JACKETING ARE SHOWN

Using the symbols given in chart 5.7, tracing is shown on the plan and elevation drawings of the plant piping and it will similarly be indicated on the isometric drawings. It will also be indicated on any model used. Tracing is one of the last aspects of plant design, and steam subheaders can either be shown directly on the piping drawings or on sepias or film prints.

## STEAM TRACING

### 6.8.3

This is a widely-used way of keeping lines warm—surplus steam is usually available for this purpose. Figure 6.40 shows typical tracing arrangements. A steam-tracing system consists of tracer lines separately fed from a steam supply header (or subheader), each tracer terminating with a separate trap. Horizontal pipes are commonly traced along the bottom by a single tracer. Multiply-traced pipe, with more than two tracers, is unusual.

## STEAM PRESSURE FOR TRACING

Steam pressures in the range 10 to 200 PSIG are used. Sometimes steam will be available at a suitable pressure for the tracing system, but if the available steam is at too high a pressure, it may be reduced by means of a control (valve) station—see 6.1.4. Low steam pressures may be adequate if tracers are fitted with traps discharging to atmospheric pressure. If a pressurized condensate system is used, steam at 100 to 125 PSIG is preferred.

## SIZING HEADERS

The best way to size a steam subheader or condensate header serving several tracers is to calculate the total internal cross-sectional area of all the tracers, and to select the header size offering about the same flow area. Table 6.9 allows quick selection if the tracers are all of the same size:

NUMBER OF TRACERS PER HEADER

TABLE 6.9

| HEADER SIZE (IN.) | SIZE OF TRACER (IN.) |     |     |     |   |
|-------------------|----------------------|-----|-----|-----|---|
|                   | 1/4                  | 3/8 | 1/2 | 3/4 | 1 |
| NUMBER OF TRACERS |                      |     |     |     |   |
| 3/4               | 9                    | 4   | 2   | 1   | — |
| 1                 | 16                   | 7   | 4   | 2   | 1 |
| 1 1/4             | 36                   | 16  | 9   | 4   | 2 |
| 2                 | 64                   | 28  | 16  | 7   | 4 |

## MAXIMUM LENGTHS & RISES

The rate at which condensate forms and fills the line determines the length of the tracer in contact with the pipe. Too many variables are involved to give useful maximum tracer lengths. Most companies have their own design figure (or figures based on experience) for this: usually, length of tracer in contact with pipe does not exceed 250 ft.

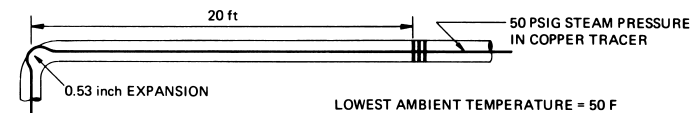
1 PSI steam will lift condensate about 2.3 ft, and therefore vertical rises will present no problem unless low-pressure steam is being used. Companies prefer to limit the vertical rise in a tracer at any one place to 6 ft (for 25-49 PSIG steam) or 10 ft (for 50-100 PSIG steam). As a rough guide, the total height, in feet, of all the rises in one tracer may be limited to one quarter of the initial steam pressure, in PSIG. For example, if the initial steam pressure is 100 PSIG, the total height of all risers in the tracer should be limited to 25 ft. The rise for a sloped tracer is the difference in elevations between the ends of the sloping part of the tracer.

## EXPANSION OF THE TRACER, & ANCHORING

Expansion can be accommodated by looping the tracer at elbows and/or providing horizontal expansion loops in the tracer. Vertical downward expansion loops obstruct draining and will cause trouble in freezing climates, unless the design includes a drain at the bottom of the loop, or a union to break the loop. It is necessary to anchor tracers to control the amount of expansion that can be tolerated in any one direction. Straight tracers 100 ft or longer are usually anchored at their midpoints.

Expansion at elbows must be limited where no loop is used and excessive movement of the tracer could lift the insulation. In such cases the tracer is anchored not more than 10 to 25 ft away from an elbow which limits start-up expansion to 1/2 to 3/4 inch in most cases. The distance of the anchor from the elbow is best calculated from the ambient and steam temperatures.

**EXAMPLE:** System traced with copper tubing: coefficient of linear expansion of copper = 0.000009 per deg F. Steam pressure to be used = 50 PSIG (equivalent steam temperature 298F). Lowest ambient temperature = 50 F. If the anchor is located 20 ft from the elbow, the maximum expansion in inches is  $(298-50)(0.000009)(20)(12) = 0.53$  in. This expansion will usually be tolerable even for a small line with the tracer construction for elbows shown in figure 6.40.



## PIPE, TUBE & FITTINGS FOR TRACING

SCH 80 carbon steel pipe, or copper or stainless steel tubing is used for tracers. Selection is based on steam pressure and required tracer size. In practice, tracers are either 1/2 or 3/8-inch size, as smaller sizes involve too much pressure drop, and larger material does not bend well enough for customary field installation.

1/2-inch OD copper tube is the most economic material for tracing straight piping. 3/8-inch OD copper tubing is more useful where small bends are required around valve bodies, etc. Copper tubing can be used for pressures up to 150 PSIG (or to 370 F). Table T-1 gives data for copper tube.

Supply lines from the header are usually socket welded or screwed and seal-welded depending on the pressures involved and the company's practice. A pipe-to-tube connector is used to make the connection between the steel pipe and tracer tube — see figure 2.41.

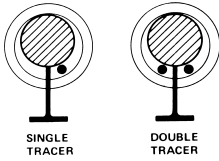
## TRACING VALVES & EQUIPMENT

Different methods are used. Some companies require valves to be wrapped with tracer tubing. Others merely run the tubing in a vertical loop alongside and against the valve body. In either method, room should be left for removing flange bolts, and unions should be placed in the tracer so that the valve or equipment can be removed.

# STEAM TRACING DETAILS

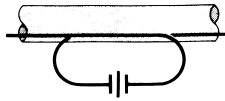
FIGURE 6.40

## PIPE

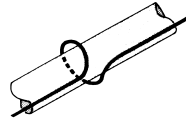


## EXPANSION

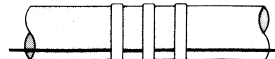
PREFERABLY TAKE UP EXPANSION AT ELBOWS



UNION TO BREAK LOOP AND DRAIN LINE IN FREEZING CONDITIONS



## ANCHORING THE TRACER

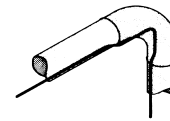


DOUBLE OR TRIPLE BAND FOR TRACER

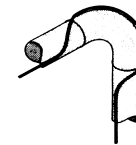


STEEL TRACER CAN BE WELDED TO FLAT BAR

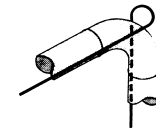
## TRACER AT ELBOWS



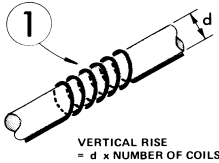
BRING TRACER TO SIDE TO ALLOW FOR EXPANSION AND TO IMPROVE HEATING OF ELBOW



TRACE BACK OF ELBOW IN FREEZING CLIMATES



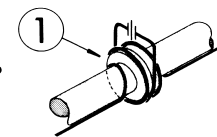
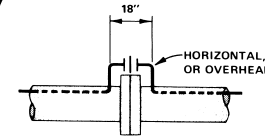
## SPIRAL WINDING



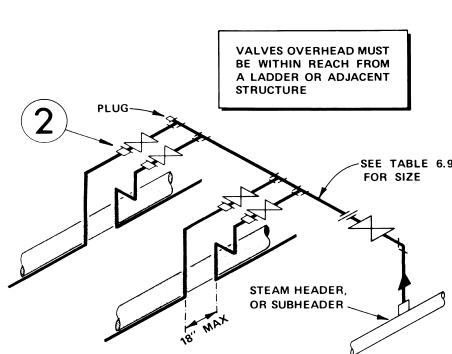
## NOTES

- (1) THE TOTAL VERTICAL RISE IS EQUAL TO THE SUM OF ALL RISERS—SEE 'MAXIMUM LENGTHS & RISES', 6.8.3
- (2) PIPE-TO-TUBE CONNECTORS ARE USED FOR JOINING SCREWED PIPING TO COPPER OR STAINLESS-STEEL TUBING. CLASS 3000 FS UNIONS ARE USED FOR CS TRACERS. UNIONS AT TRACER TERMINATIONS ARE COVERED BY THE TRAP SYMBOL—SEE FIGURES 6.43 AND 6.44
- (3) FOR FREEZING CLIMATES, USE TRACING ARRANGEMENTS THAT CAN DRAIN, OR PROVIDE FOR AIR PURGING

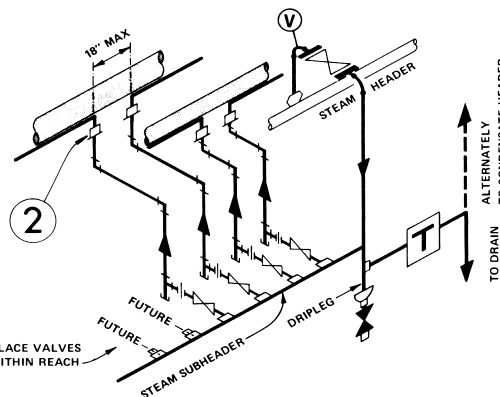
## TRACER AT FLANGES



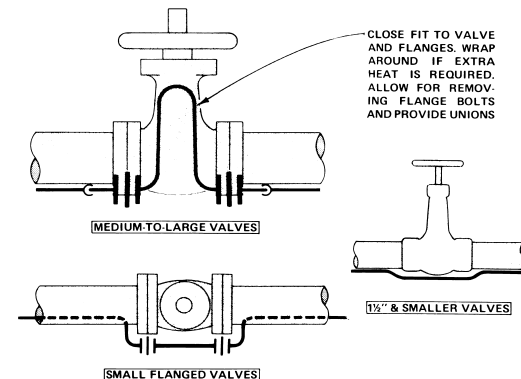
## STEAM SUPPLY



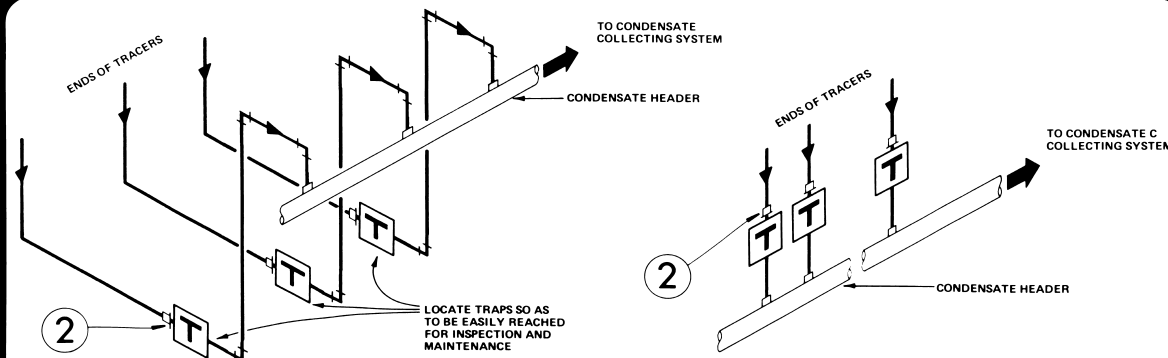
VALVES OVERHEAD MUST BE WITHIN REACH FROM A LADDER OR ADJACENT STRUCTURE



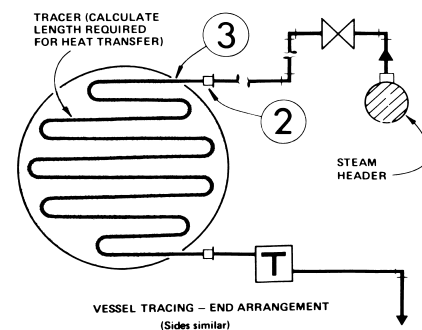
## TRACER AT VALVES



## CONDENSATE RETURN



## TRACING VESSELS



## DESIGN POINTS FOR STEAM TRACING & INSULATION

- Run tracers parallel to and against the underside of the pipe to be heated
- Ensure that the temperature limit for process material is not exceeded by the temperature of the steam supplying the tracer. Hot spots occur at bands—see 6.8.2, under ‘Getting heat to the process line’
- Run a steam subheader from the most convenient source if there is no suitable existing steam supply that can be used either directly or by reducing the pressure of the available steam
- Take tracer lines separately from the top of the subheader, and provide an isolating valve in the horizontal run
- Feed steam first to the highest point of the system of lines to be traced, so that gravity will assist the flow of condensate to trap(s) and condensate header
- Do not split (branch) a tracer and then rejoin—the shorter limb would take most of the steam
- Preferably, absorb expansion of the tracer at elbows. If loops are used in the line, arrange them to drain on shutdown
- Keep loops around flanges horizontal or overhead, and provide unions so that tracers can be disconnected at flanges
- If possible, group supply points and traps, locating traps at grade or platform level
- Do not place a trap at every low point of a tracer (as is the practice with steam lines) but provide a trap at the end of the tracer
- Do not run more than one tracer to a trap
- Increased heating may be obtained:
  - (1) By using more than one tracer
  - (2) By winding the tracer in a spiral around the line
  - (3) By applying heat-transfer cement to the tracer and line
  - (4) By welding the tracer to the line—refer to 6.8.2, under ‘Getting heat to the process line’
- Reserve spiral winding of tracers for vertical lines where condensate can drain by gravity flow
- In freezing conditions, provide drains at low points—and at other points where condensate could collect during shutdown
- Provide slots in insulation to accommodate expansion of the tracer where it joins and leaves the line to be traced
- Indicate thickness of insulation to envelop line and tracer, and show whether insulation is also required at flanges
- Indicate limits for insulation for personnel protection—see 6.8.1, under ‘How thick should insulation be?’, and chart 5.7
- Provide crosses instead of elbows and flanged joints at intervals in heated lines conveying materials which may solidify, to permit cleaning if the heating fails

## STEAM & LOW-PRESSURE HEATING MEDIA

6.9

### EXPLANATIONS OF STEAM TERMS

6.9.1

#### HOW STEAM IS FORMED

Steam is a convenient and easily handled medium for heating, for driving machinery, for cleaning, and for creating vacuum.

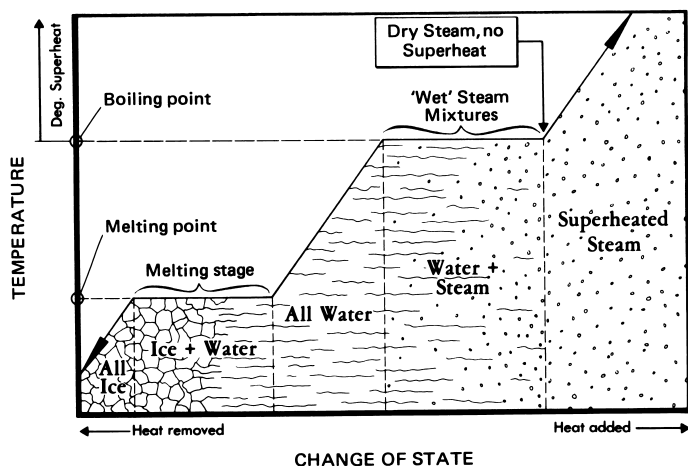
After water has reached the boiling point, further addition of heat will convert water into the vapor state: that is, steam. During boiling there is no further rise in temperature of the water, but the vaporization of the water uses up heat. This added heat energy, which is not shown by a rise in temperature, is termed 'latent heat of vaporization', and varies with pressure.

In boiling one pound of water at atmospheric pressure (14.7 PSIA) 970.3 BTU is absorbed. If the steam condenses back into water (still at the boiling temperature and 14.7 PSIA) it will release exactly the amount of heat it absorbed on vaporizing.

The term 'saturated steam' refers to both *dry steam* and *wet steam*, described below. Steam tables give pressure and temperature data applicable to dry and to wet steam. Small amounts of air, carbon dioxide, etc., are present in steam from industrial boilers.

STEAM/WATER/ICE DIAGRAM

CHART 6.3



#### DRY STEAM

Dry steam is a gas, consisting of water vapor only. Placed in contact with water at the same temperature, dry steam will not condense, nor will more steam form—liquid and vapor are in equilibrium.

#### WET STEAM

Wet steam consists of water vapor and suspended water particles at the same temperature as the vapor. Heating ability ('quality') varies with the percentage of dry steam in the mixture (the water particles contain no latent heat of vaporization). Like dry steam, wet steam is in equilibrium with water at the same temperature.

#### SUPERHEATED STEAM

If heat is added to a quantity of dry steam, the temperature of the steam will rise, and the number of degrees rise in temperature is the 'degrees of superheat'. Thus, superheat is 'sensible' heat — that is, it can be measured by a thermometer.

#### EFFECT OF PRESSURE CHANGE

Under normal atmospheric pressure (14.7 PSIA) pure water boils at 212 F. Reduction of the pressure over the water will lower the boiling point. Increase in pressure raises the boiling point. Steam tables give boiling points corresponding to particular pressures.

#### FLASH STEAM

Suppose a quantity of water is being boiled at 300 PSIA (corresponding to 417 F). If the source of heat is removed, boiling ceases. If the pressure over the water is then reduced, say from 300 to 250 PSIA, the water starts boiling on its own, without any outside heat applied, until the temperature drops to 401 F (this temperature corresponds to 250 PSIA). Such spontaneous boiling due to reduction in pressure is termed 'flashing', and the steam produced, 'flash steam'.

The data provided in steam tables enable calculation of the quantity and temperature of steam produced in 'flashing'.

#### CONDENSATE — WHAT IT IS & HOW IT FORMS

Steam in a line will give up heat to the piping and surroundings, and will gradually become 'wetter', its temperature remaining the same. The change of state of part of the vapor to liquid gives heat to the piping without lowering the temperature in the line. The water that forms is termed 'condensate'. If the line initially contains superheated steam, heat lost to the piping and surroundings will first cause the steam to lose sensible heat until the steam temperature drops to that of dry steam at the line pressure.

#### AIR IN STEAM

With both dry and wet steam, a certain pressure will correspond to a certain temperature. The temperature of the steam at various pressures can be found in steam tables. If air is mixed with steam, this relationship between pressure and temperature no longer holds. The more air that is admixed, the more the temperature is reduced below that of steam at the same pressure. There is no practicable way to separate air from steam (without condensation) once it is mixed.

#### LOW-PRESSURE HEATING MEDIA

6.9.2

Special liquid media such as Dowtherms (Dow Chemical Co.) and Therminols (Monsanto Co.) can be boiled like water, but the same vapor temperatures as steam are obtained at lower pressures. Heating systems using these liquids are more complicated than steam systems, and experience with them is necessary in order to design an efficient installation. However, the basic principles of steam-heating systems apply.

## STEAM PIPING

### 6.10

#### REMOVING AIR FROM STEAM LINES

##### 6.10.1

Air in steam lines lowers the temperature for a given pressure, and calculated rates of heating may not be met. See 6.9.1 under 'Air in steam'.

The most economic means for removing air from steam lines is automatically thru temperature-sensitive traps or traps fitted with temperature-sensitive air-venting devices placed at points remote from the steam supply. When full line temperature is attained the vent valves will close completely. See 6.10.7 under 'Temperature-sensitive (or thermostatic) traps'.

#### WHY PLACE VENTS AT REMOTE POINTS ?

On start-up, cold lines will be filled with air. Steam issuing from the source will mix with some of this air, but will also act as a piston pushing air to the remote end of each line.

#### WHY REMOVE CONDENSATE ?

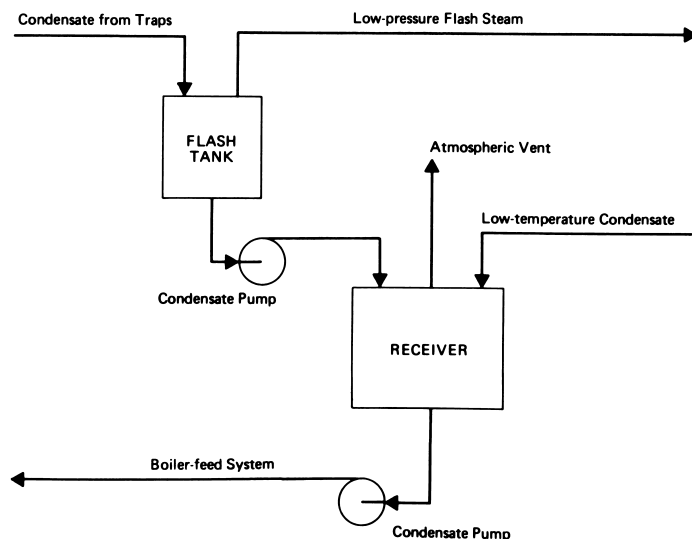
##### 6.10.2

In heating systems using steam with little or no superheat, steam condenses to form water, termed 'condensate', which is essentially distilled water. Too valuable to waste, condensate is returned for use as boiler feedwater unless it is contaminated with oil (usually from a steam engine) or unless it is uneconomic to do so, when it can either be used locally as a source of hot water, or run to a drain. If condensate is not removed:—

- Steam with entrained water droplets will form a dense water film on heat transfer surfaces and interfere with heating
- Condensate can be swept along by the rapidly-moving steam (at 120 ft/sec or more) and the high-velocity impact of slugs of water with fittings, etc. (waterhammer) may cause erosion or damage

#### UTILIZING CONDENSATE

FIGURE 6.41



In early steam systems, there was considerable waste of steam and condensate after passing thru heating coils, etc., as steam was merely vented to the open air. Later, the wastefulness of this resulted in closed steam lines from which only the condensed steam was removed and then re-fed to the boiler. The removal of condensate to atmospheric pressure was effected with traps—special automatic discharge valves—see 6.10.7.

This was a much more efficient system, but it still wasted flash steam. On passing thru the traps, the depressurized condensate boiled, generating lower-pressure steam. In modern systems, this flash steam is used and the residual condensate returned to the boiler.

#### STEAM SEPARATOR OR DRYER

##### 6.10.3

This is an in-line device which provides better drying of steam being immediately fed to equipment. A separator is shown in figure 2.67. It separates droplets entrained in the steam which have been picked up from condensate in the pipe and from the pipe walls, by means of one or more baffles (which cause a large pressure drop). The collected liquid is piped to a trap.

#### SLOPING & DRAINING STEAM & CONDENSATE LINES

##### 6.10.4

Sloping of steam and condensate lines is discussed in 6.2.6, under 'Sloped lines avoid pocketing and aid draining'.

Condensate is collected from a steam line either by a steam separator (sometimes termed a 'dryer')—see 6.10.3 above—or more cheaply by a dripleg (drip pocket or well — see below) from where it passes to a trap for periodic discharge to a condensate return line or header which will be at a lower pressure than the steam line. The header is either taken to a boiler feedwater tank feeding make-up water to the boiler or to a hotwell for pumping to the boiler feedwater tank.

#### DRIPLEGS COLLECT CONDENSATE

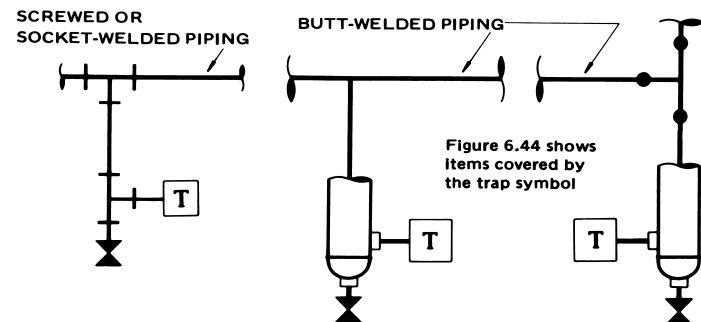
##### 6.10.5

It is futile to provide a small dripleg or drain pocket on large lines, as the condensate will not be collected efficiently.

Driplegs are made from pipe and fittings. Figure 6.42 shows three methods of construction, and table 6.10 suggests dripleg and valve sizes.

#### DRIPLEG CONSTRUCTIONS

FIGURE 6.42



| DIMENSIONS & SIZES (NOMINAL) IN INCHES |   |    |    |    |    |    |    |    |    |    |    |    |
|--|---|----|----|----|----|----|----|----|----|----|----|----|
| LINE SIZE                              | * | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
| DIMENSION 'A'                          |   | 3  | 4  | 6  | 6  | 8  | 8  | 10 | 12 | 12 | 12 | 12 |
| DIMENSION 'B'                          |   | 12 | 12 | 14 | 14 | 16 | 16 | 18 | 20 | 21 | 22 | 24 |
| SIZE OF V <sub>1</sub>                 |   | ¾  | ¾  | ¾  | ¾  | ¾  | ¾  | 1  | 1  | 1  | 1  | 1  |
| SIZE OF V <sub>2</sub>                 |   | ¾  | ¾  | ¾  | ¾  | ¾  | 1  | 1  | 1  | 1  | 1  | 1  |

TO 2"

\*For lines 2-inch and smaller, use ¾-inch pipe, valves and fittings, reducing line size at the trap as necessary

Figure 2.70 shows dripleg construction

### STEAM LINE PRESSURE FORCES CONDENSATE INTO RECOVERY SYSTEM

6.10.6

In almost every steam-heating system where condensate is recovered the trapped condensate has to be lifted to a condensate header and run to a boiler feedwater tank, either directly or via a receiver. Each PSI of steam pressure behind a trap can lift the condensate about two feet vertically. The pressure available for lifting the condensate is the pressure difference between the steam and condensate lines less any pressure drop over pipe, valves, fittings, trap, etc.

### STEAM TRAPS

6.10.7

The purpose of fitting traps to steam lines is to obtain fast heating of systems and equipment by freeing the steam lines of condensate and air. A steam trap is a valve device able to discharge condensate from a steam line without also discharging steam. A secondary duty is to discharge air—at start-up, lines are full of air which has to be flushed out by the steam, and in continuous operation a small amount of air and non-condensable gases introduced in the boiler feedwater have also to be vented.

Some traps have built-in strainers to give protection from dirt and scale which may cause the trap to jam in an open position. Traps are also available with checking features to safeguard against backflow of condensate. Refer to the manufacturers' catalogs for details.

Choosing a trap from the many designs should be based on the trap's ability to operate with minimal maintenance, and on its cost. To reduce inventory and aid maintenance, the minimum number of types of trap should be used in a plant. The assistance of manufacturers' representatives should be sought before trap types and sizes are selected.

Steam traps are designed to react to changes in temperature, pressure or density:

**TEMPERATURE-SENSITIVE (or 'THERMOSTATIC') TRAPS** are of two types: The first type operates by the movement of a liquid-filled bellows, and the second uses a bimetal element. Both types are open when cold and readily discharge air and condensate at start-up. Steam is in direct contact with the closing valve and there is a time delay with both types in operating. A large dripleg allowing time for condensate to cool improves operation. As these traps are actuated by temperature differential, they are economic at steam pressures greater than 6 PSIG. The temperature rating of the bellows and the possibility of damage by waterhammer should be considered—refer to 6.10.8.

**IMPULSE TRAPS** are also referred to as 'thermodynamic' and 'controlled disc'. These traps are most suited to applications where the pressure downstream of the trap is less than about half the upstream pressure. Waterhammer does not affect operation. They are suitable for steam pressures over 8 PSIG.

**DENSITY-SENSITIVE TRAPS** are made in 'float' and 'bucket' designs. The *float trap* is able to discharge condensate continuously, but this trap will not discharge air unless fitted with a temperature-sensitive vent (the temperature limitation of the vent should be checked). Float traps sometimes may fail from severe waterhammer. The *inverted bucket trap* (see 3.1.9) is probably the most-used type. The trap is open when cold, but will not discharge large quantities of air at startup unless the bucket is fitted with a temperature-sensitive vent. The action in discharging condensate is rapid. Steam will be discharged if the trap loses its priming water due to an upstream valve being opened; refer to note (9) in the key to figure 6.43. Inverted bucket traps will operate at pressures down to 1/4 PSIG.

### FLASHING

6.10.8

Refer to 6.9.1. When hot condensate under pressure is released to a lower pressure return line, the condensate immediately boils. This is referred to as 'flashing' and the steam produced as 'flash steam'.

The hotter the steam line and the colder the condensate discharge line, the more flashing will take place; it can be severe if the condensate comes from high pressure steam. Only part of the condensate forms steam. However, if the header is inadequately sized to cope with the quantity of flash steam produced and backpressure builds up, waterhammer can result.

Often, where a trap is run to a drain, a lot of steam seems to be passing thru the trap, but this is usually only from condensate flashing.

### DRAINING SUPERHEATED STEAM LINES

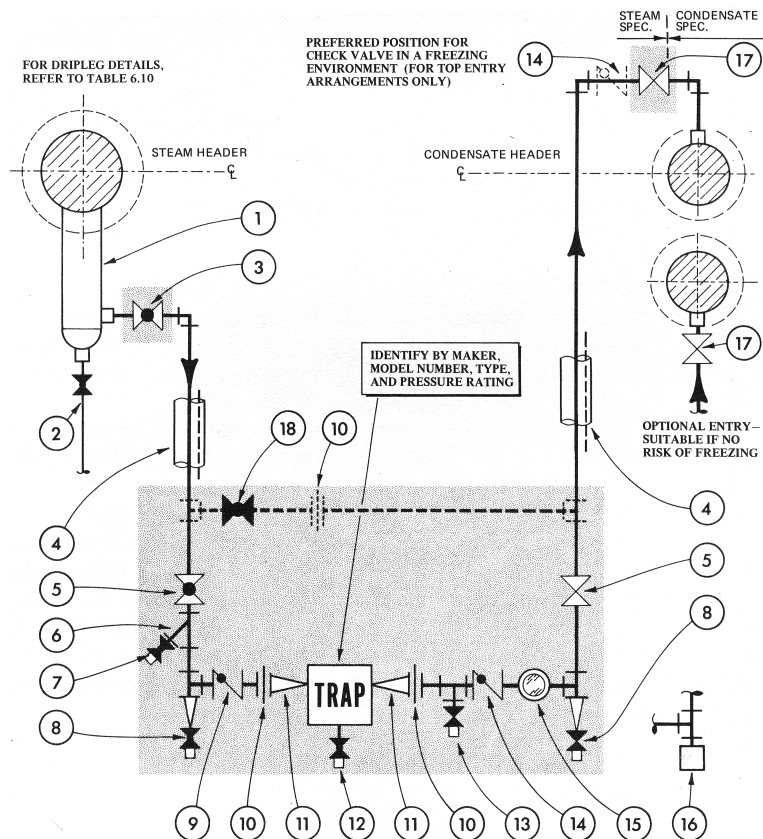
6.10.9

Steam lines with more than a few degrees of superheat will not usually form condensate in operation. During the warming-up period after starting a cold circuit, the large bulk of metal in the piping will nearly always use up the degrees of superheat to produce a quantity of condensate.

# STEAM-TRAP PIPING

## FOR COLLECTED CONDENSATE

FIGURE 6.43



## KEY

FIGURES 6.43 & 6.44 SHOW EQUIPMENT WHICH CAN BE USED IN TRAP PIPING ARRANGEMENTS. ONLY ITEMS OF EQUIPMENT NECESSARY FOR ECONOMIC & SAFE DESIGN NEED BE USED. THE FOLLOWING NOTES WILL AID SELECTION

- (1) DRIPLEG FROM STEAM HEADER, OR LINE TO EQUIPMENT, OR LINE FROM STEAM-FED EQUIPMENT
- (2) DRIPLEG VALVE FOR PERIODICALLY BLOWING DOWN SEDIMENT. FOR SAFETY, VALVE SHOULD BE PIPED TO A DRAIN OR TO GRADE
- (3) ISOLATING VALVE TO BE LOCATED CLOSE TO DRIPLEG
- (4) ★ INSULATION, NEEDED IN A COLD ENVIRONMENT IF THERE IS A RISK OF CONDENSATE FREEZING AS A RESULT OF SHUTDOWN OR INTERMITTENT OPERATION. IN EXTREME COLD, TRACING MAY ALSO BE REQUIRED—IF STEAM IS NOT CONSTANTLY AVAILABLE FOR THIS PURPOSE, ELECTRIC TRACING WOULD BE NECESSARY
- (5) ★ ISOLATING VALVE. REQUIRED ONLY IF VALVES (3) AND (17) ARE OUT OF REACH, OR IF A BYPASS IS USED—SEE NOTE (18)
- (6) STRAINER. NORMALLY FITTED IN LINES TO TRAPS OF LESS THAN 2-INCH SIZE. A STRAINER MAY BE AN INTEGRAL FEATURE OF THE TRAP
- (7) ★ VALVE FOR BLOWING STRAINER SEDIMENT TO ATMOSPHERE. PLUG FOR SAFETY
- (8) ★ MANUALLY-OPERATED DRAIN VALVE FOR USE IN FREEZING CONDITIONS WHEN THE TRAP IS POSITIONED HORIZONTALLY—SEE NOTE (16)
- (9) ★ CHECK VALVE. PRIMARILY REQUIRED IN LINES USING BUCKET TRAPS TO PREVENT LOSS OF SEAL WATER IF DIFFERENTIAL PRESSURE ACROSS TRAP REVERSES DUE TO BLOWING DOWN THE LINE OR STRAINER UPSTREAM OF THE TRAP
- (10) UNIONS FOR REMOVING TRAP, ETC
- (11) ★ SWAGES FOR ADAPTING TRAP TO SIZE OF LINE
- (12) ★ BLOWDOWN VALVE FOR A TRAP WITH A BUILT-IN STRAINER (ALTERNATIVE TO (6))
- (13) ★ TEST VALVE SHOWS IF A FAULTY TRAP IS PASSING STEAM. SOMETIMES, BODY OF TRAP HAS A TAPPED PORT FOR FITTING THIS VALVE
- (14) ★ CHECK VALVE PREVENTS BACKFLOW THRU TRAP IF CONDENSATE IS BEING RETURNED TO A HEADER FROM MORE THAN ONE TRAP. IN THE LOWER POSITION, THE VALVE HAS THE ASSISTANCE OF A COLUMN OF WATER TO HELP IT CLOSE AND TO GIVE IT A WATER SEAL. REQUIRED IF SEVERAL TRAPS DISCHARGE INTO A SINGLE HEADER WHICH IS OR MAY BE UNDER PRESSURE
- (15) ★ SIGHT GLASS ALLOWS VISUAL CHECK THAT TRAP IS DISCHARGING CORRECTLY INTO A PRESSURIZED CONDENSATE RETURN LINE, BUT IS SELDOM USED BECAUSE THE GLASS MAY ERODE, PRESENTING A RISK OF EXPLOSION
- (16) ★ TEMPERATURE-SENSITIVE (AUTOMATIC) DRAIN ALLOWS LINE TO EMPTY, PREVENTING DAMAGE TO PIPING IN A COLD ENVIRONMENT (SEE NOTE (4)). IF VALVE (14) IS OVER-HEAD, THE AUTOMATIC DRAIN MAY BE FITTED TO THE TRAP — SOME TRAP BODIES PROVIDE FOR THIS
- (17) ISOLATING VALVE AT HEADER
- (18) ★ BY-PASS. NOT RECOMMENDED AS IT CAN BE LEFT OPEN. IT IS BETTER TO PROVIDE A STANDBY TRAP

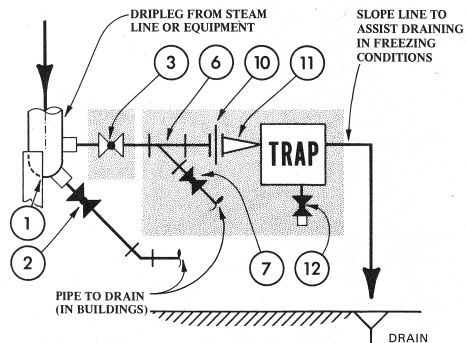
□ □ □ □ □ □ □ □

★ ASTERISK INDICATES THAT THE EQUIPMENT IS OPTIONAL AND IS NOT ESSENTIAL TO THE BASIC TRAP PIPING DESIGN

## FOR DRAINED CONDENSATE

FIGURE 6.44

## SYMBOL



Pipe, fittings and valves within shaded areas in figures 6.43 and 6.44 are shown on drawings by the above symbol

Start-ups are infrequent and with more than a few degrees of superheat it is unnecessary to trap a system which is continuously operated. These superheated steam lines can operate with driplegs only, and are usually fitted with a blowdown line having two valves so that condensate can be manually released from the dripleg after startup.

A superheated steam supply to an intermittently operated piece of equipment will require trapping directly before the controlling valve for the equipment, as the temperature will drop at times allowing condensate to form.

#### PREVENT TRAPS FROM FREEZING

6.10.10

Insulation and steam or electric tracing of the trap and its piping may also be required in freezing environments. Temperature-sensitive and impulse traps are not subject to freezing trouble if mounted correctly, so that the trap can drain. Bucket traps are always mounted with the bucket vertical and a type with top inlet and bottom outlet should be chosen, unless the trap can be drained by fitting an automatic drain.

#### GUIDELINES TO STEAM TRAP PIPING

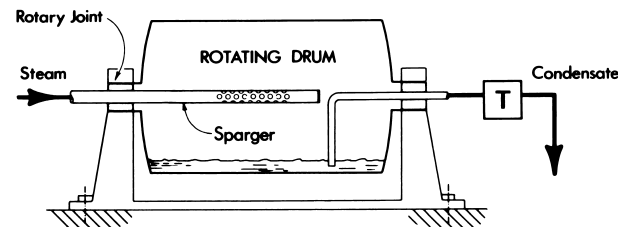
6.10.11

- Figures 6.43 thru 6.45 are a guide to piping traps from driplegs, lines, vessels, etc.
- Try to group traps to achieve an orderly arrangement
- Unless instructed otherwise, pipe, valves and fittings will be the same size as the trap connections, but not smaller than 3/4 in.
- Traps are normally fitted at a level lower than the equipment or dripleg that they serve
- Trap each item of equipment using steam separately, even if the steam pressure is common
- Provide driplegs (and traps on all steam lines with little or no superheat) at low points before or at the bottom of risers, at pockets and other places where condensate collects on starting up a cold system. Table 6.10 gives dripleg sizes
- Locate driplegs at the midpoints of exchanger shells, short headers, etc. If dual driplegs are provided it is better to locate them near each end
- For installations in freezing conditions, where condensate is wasted, preferably choose traps that will not pocket water and which can be installed vertically, to allow draining by gravity. Otherwise, select a trap that can be fitted with an automatic draining device by the manufacturer
- Avoid long horizontal discharge lines in freezing conditions, as ice can form in the line from the trap. Keep discharge lines short and pitch them downward, unless they are returning condensate to a header
- For efficient operation of equipment such as heat exchangers using large amounts of steam, consider installing a separator in the steam feed

- 'Syphon' removal of condensate: In certain instances it is not possible to provide a gravity drain path – for example, where condensate is formed inside a rotating drum. The pressure of the steam is used to force ('syphon') the condensate up a tube and into a trap. Figure 6.45 shows such an arrangement

TRAPPING ARRANGEMENT FOR ROTATING DRUM

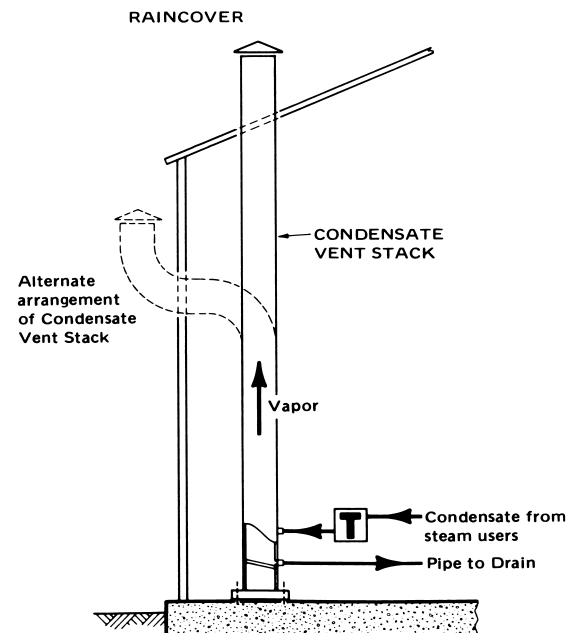
FIGURE 6.45



- If condensate is continuously discharging to an open drain in an inside installation a personnel hazard or objectionable atmosphere may be created. To correct this, discharge piping can be connected to an exhaust stack venting to atmosphere and a connection to the main drain provided, as in figure 6.46

CONDENSATE VENT STACK

FIGURE 6.46



## WHY VENTS ARE NEEDED

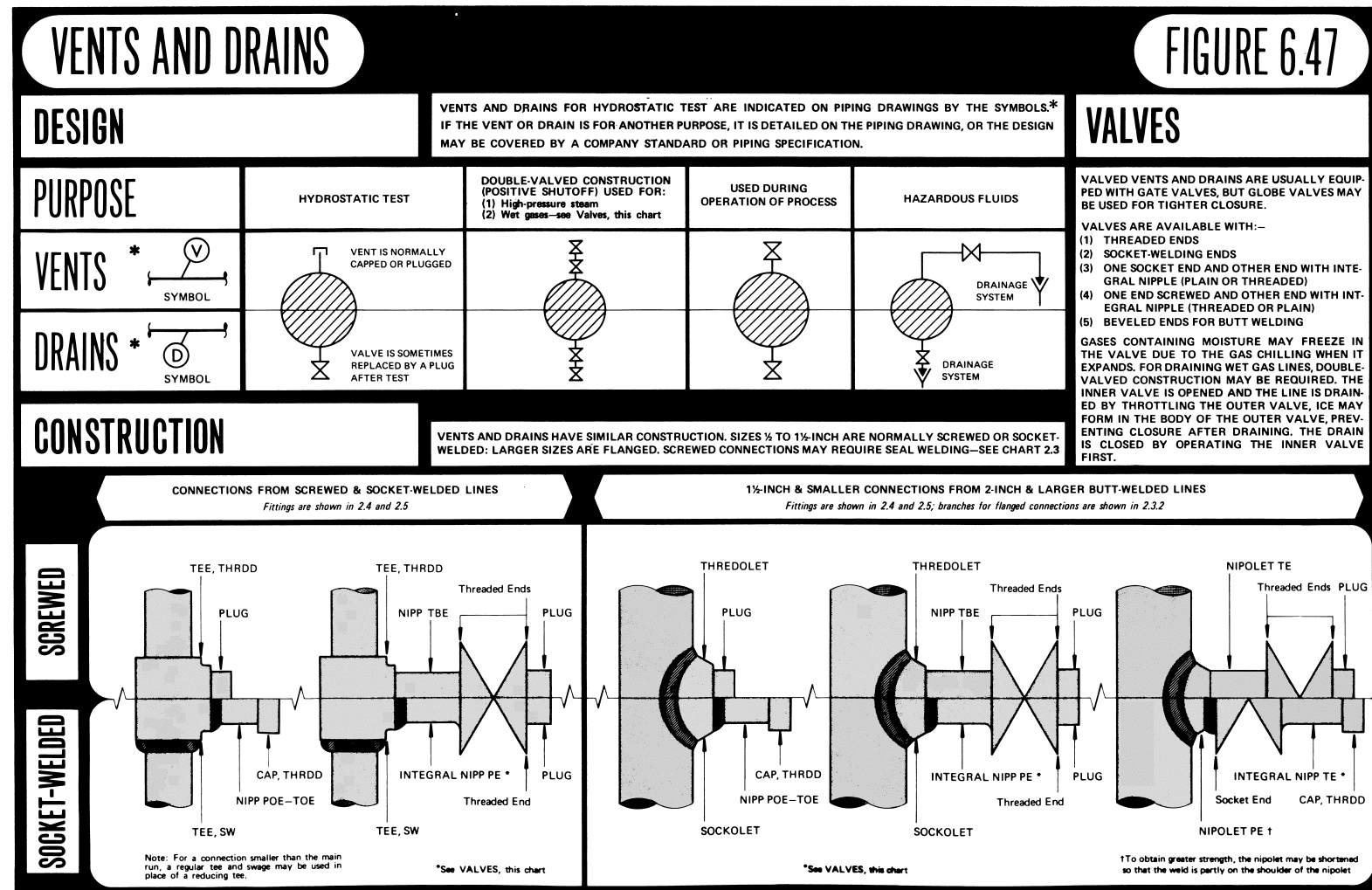
### 6.11.1

Vents are needed to let gas (usually air) in and out of systems. When a line or vessel cools, the pressure drops and creates a partial vacuum which can cause syphoning or prevent draining. When pressure rises in storage tanks due to an increase in temperature, it is necessary to release excess pressure. Air must also be released from tanks to allow filling, and admitted to permit draining or pumping out liquids.

Unless air is removed from fuel lines to burners, flame fading can result. In steam lines, air reduces heating efficiency.

After piping has been erected, it is often necessary to subject the system to a hydrostatic test to see if there is any leakage. In compliance with the applicable code, this consists of filling the lines with water or other liquid, closing the line, applying test pressure, and observing how well pressure is maintained for a specified time, while searching for leaks.

As the test pressure is greater than the operating pressure of the system, it is necessary to protect equipment and instruments by closing all relevant valves. Vessels and equipment usually are supplied with a certificate of code compliance. After testing, the valved drains are opened and the vent plugs temporarily removed to allow air into the piping for complete draining.



Positions of the required vent and drain points are established on the piping drawings. (P&ID's will show only process vents, such as vacuum breakers, and process drains.) Refer to figure 6.47 for construction details.

## VENTING GASES

6.11.3

Quick-opening vents of ample size are needed for gases. Safety and safety-relief valves are the usual venting means. See 3.1.9 for pressure-relieving devices, and 6.1.3, under 'Piping safety and relief valves'.

Gases which offer no serious hazard after some dilution with air may be vented to atmosphere by means ensuring that no direct inhalation can occur. If a (combustible) gas is toxic or has a bad odor, it may be piped to an incinerator or flarestack, and destroyed by burning.

## DRAINING COMPRESSED-AIR LINES

6.11.4

Air has a moisture content which is partially carried thru the compressing and cooling stages. It is this moisture that tends to separate, together with any oil, which may have been picked up by the air in passing thru the compressor.

If air for distribution has not been dried, distribution lines should be sloped toward points of use and drains: lines carrying dried air need not be sloped. Sloping is discussed in 6.2.6.

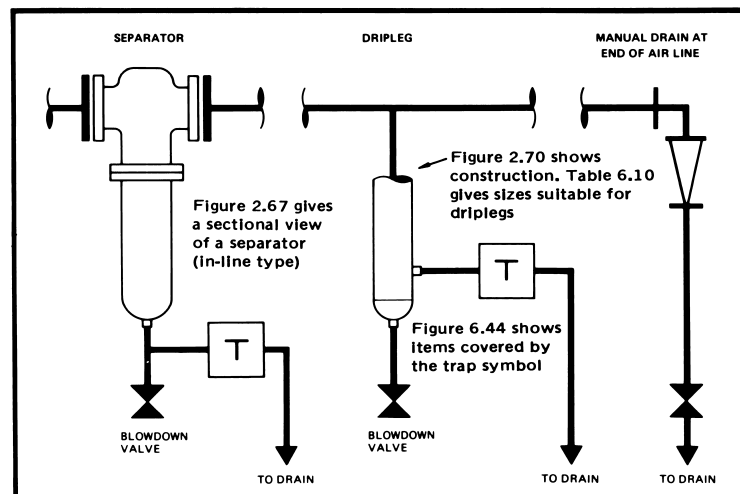


If the compressed-air supply is not dried, provide:—

- (1) Traps at all drains from equipment forming or collecting liquid—such as intercooler, aftercooler, separator, receiver.
- (2) Driplegs with traps on distribution headers (at low points before rises) and traps or manual drains at the ends of distribution headers.

## LIQUID REMOVAL FROM AIR LINES

FIGURE 6.48



## RELIEVING PRESSURE—LIQUIDS

6.12

The buildup of pressure in a liquid is halted by discharging a small amount of liquid. Relieving devices having large ports are not required. Relief valves—see 3.1.9—are used, and need to be piped at the discharge side, but the piping should be kept short. See 6.1.3 under 'Piping safety & relief valves'.

Rarely will the relieved liquid be sufficiently non-hazardous to be piped directly to a sewer. Often the liquid is simply to be reclaimed. Relieved liquid is frequently piped to a 'knockout drum', or to a sump or other receiver for recovery. The P&ID should show what is to be done with the relieved liquid.

## RELIEF HEADERS

6.12.1

Headers should be sized to handle adequately the large amounts of vapor and liquid that may be discharged during major mishap. Relief headers taken to knockout drums, receivers or incinerators, are normally sloped. Refer to 6.2.6 and figure 6.3, showing the preferred location of a relief header on a piperack.

## WASTES & EFFLUENTS

6.13

Manufacturing processes may generate materials that cannot be recycled, and for which there is no commercial use. These materials are termed 'waste products', or 'wastes'. An 'effluent' is any material flowing from a plant site to the environment. Effluents need not be polluting: for example, properly-treated waste water may be discharged without harming the environment or sewage-treatment plants.

Restrictions on the quantities and nature of effluents discharged into rivers, sewers or the atmosphere, necessitate treatment of wastes prior to discharge. Waste treatment is increasingly a factor in plant design, whether wastes are processed at the plant, or are transported for treatment elsewhere. For in-plant treatment, waste-treatment facilities are described on separate P&ID's (see 5.2.4) and should be designed in consultation with the responsible local authority.

Liquid wastes have to be collected within a plant, usually by a special drainage system. Corrosive and hazardous properties of liquid wastes will affect the choice and design of pipe, fittings, open channels, sumps, holding tanks, settling tanks, etc. Because many watery wastes are acidic and corrosive to carbon steel, collection and drainage piping is often lined or made of alloy or plastic. Sulfates frequently appear in wastes, and special concretes may be necessary for sewers, channels, sumps, etc., because sulfates deteriorate regular concretes.

Flammable wastes may be recovered and/or burned in smokeless incinerators or flarestacks. Vapors from flammable liquids present serious explosion hazards in collection and drainage systems, especially if the liquid is insoluble and floats.

Wastes may be held permanently at the manufacturing site. Solid wastes may be piled in dumps, or buried. Watery wastes containing solids may be pumped into artificial 'ponds' or 'lagoons', where the solids settle.

## SAFETY GUIDELINES FOR FLAMMABLE LIQUIDS 6.14

### REFERENCES

'Fire hazard properties of flammable liquids, gases, volatile solids'. 1984. NFPA 325M

'Flammable and combustible liquid code'. 1987. NFPA 30

'Flammable and combustible liquid code handbook'. Third edition. 1987. NFPA

'Fire protection in refineries'. Sixth edition. 1984 American Petroleum Institute. API RP 2001

'Protection against ignitions arising out of static, lightning and stray currents'. Fourth edition. 1982. API RP 2003

'Inspection for fire protection'. First edition. 1984. API RP 2004

'Welding or hot-tapping on equipment containing flammables'. 1985. API RP 2201

'Guide for fighting fire in and around petroleum storage tanks'. 1980 API publication 2021

NFPA address: Batterymarch Park, Quincy MA 02269

### TANK SPACINGS (NFPA)

TABLE 6.11

| CONDITIONS  | MINIMUM INTER-TANK CLEARANCE  |
|---|---|
| FLAMMABLE or COMBUSTIBLE LIQUID STORAGE TANKS<br>(Not exceeding 150 ft. dia.)                                   | Whichever is greater:—<br>3ft<br>(Sum of diameters of adjacent tanks)/6   |
| CRUDE PETROLEUM<br>126,000 gal max tank size<br>Non-congested locale  | 3 ft  |
| UNSTABLE FLAMMABLE and UNSTABLE COMBUSTIBLE LIQUID STORAGE TANKS  | (Sum of diameters of adjacent tanks)/2  |
| LIQUEFIED PETROLEUM GAS CONTAINER from Flammable or Combustible Liquid Storage Tank                             | 20 ft   |
| LIQUEFIED PETROLEUM GAS CONTAINER outside diked area containing Flammable or Combustible Liquid Storage Tank(s) | 10 ft from centerline of dike wall<br>NOTE: If LPG container is smaller than 125 gal (US) and each liquid storage tank is smaller than 660 gal, exemption applies |
| TANKS surrounded by other Tanks   | Authority Limit   |

*For minimum clearances from property lines, public ways and buildings, consult the National Fire Code Vol 1, NFPA 30. 1987. Chap. 2*

LPG tanks: Title 29 of the Code of Federal Regulations. 1989. Chapter XVII, part 1910-110, the US Department of Labor's 'Occupational Safety and Health Administration's' tables H-23, H-33, gives clearances. Part 1919-111 advises on the storage and handling of anhydrous ammonia.

### SOME GUIDELINES

- Apply the recommendations relating to the project of the NFPA, API or other advisory body
- Check insurer's requirements
- Isolate flammable liquid facilities so that they do not endanger important buildings or equipment. In main buildings, isolate from other areas by firewalls or fire-resistive partitions, with fire doors or openings and with means of drainage
- Confine flammable liquid in closed containers, equipment, and piping systems. Safe design of these should have three primary objectives: (1) To prevent uncontrolled escape of vapor from the liquid. (2) To provide rapid shut-off if liquid accidentally escapes. (3) To confine the spread of escaping liquid to the smallest practicable area
- If tanks containing flammable material are sited in the open, it is good practice to space them according to the minimum separations set out in the NFPA Code (No. 395. 'Farm storage of flammable liquids') and to provide dikes (liquid-retaining walls) around groups of tanks. Additional methods for dealing with tank fires are: (1) To transfer the tank's contents to another tank. (2) To stir the contents to prevent a layer of heated fuel forming
- Locate valves for emergency use in plant mishap or fire—see 6.1.3
- Valves for emergency use should be of fast-acting type
- Provide pressure-relief valves to tanks containing flammable liquid (or liquefied gas) if exposed to strong sunlight and/or high ambient temperature, so that vapor under pressure can escape
- Consider providing water sprays for cooling tanks containing flammable liquid which are exposed to sunlight
- Provide ample ventilation in buildings for all processing operations so that vapor concentration is always below the lower flammability limit. Process ventilation should be interlocked so that the process cannot operate without it
- Install explosion panels in buildings to relieve explosion pressure and reduce structural damage
- Install crash panels for personnel in hazardous areas
- Ensure that the basic protection, automatic sprinklers, is to be installed
- Some hazards require special fixed extinguishing systems—foam, carbon dioxide, dry chemical or water spray—in addition to sprinklers. Seek advice from the fire department responsible for the area, and from the insurers

## BUILDINGS IN RELATION TO PIPING

6.15

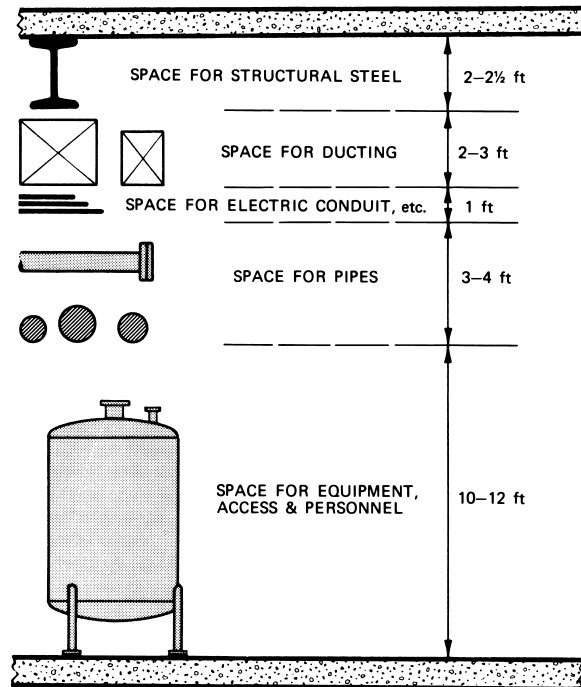
### SPACE BETWEEN FLOORS

6.15.1

To avoid interferences and to simplify design, adequate height is necessary between floors in buildings and plants for piping, electrical trays, and air ducts if required. Figure 6.49 suggests vertical spacings:

#### VERTICAL SPACING BETWEEN FLOOR & CEILING

FIGURE 6.49



### INSTALLATION OF LARGE SPOOLS & EQUIPMENT

6.15.2

Large openings in walls, floors or the roof of a building may be needed for installing equipment. Wall and roof openings are covered when not in use, but sometimes floor openings are permanent and guarded with railings, etc.

### BUILDING LAYOUT

6.15.3

#### RELATION TO PROCESS

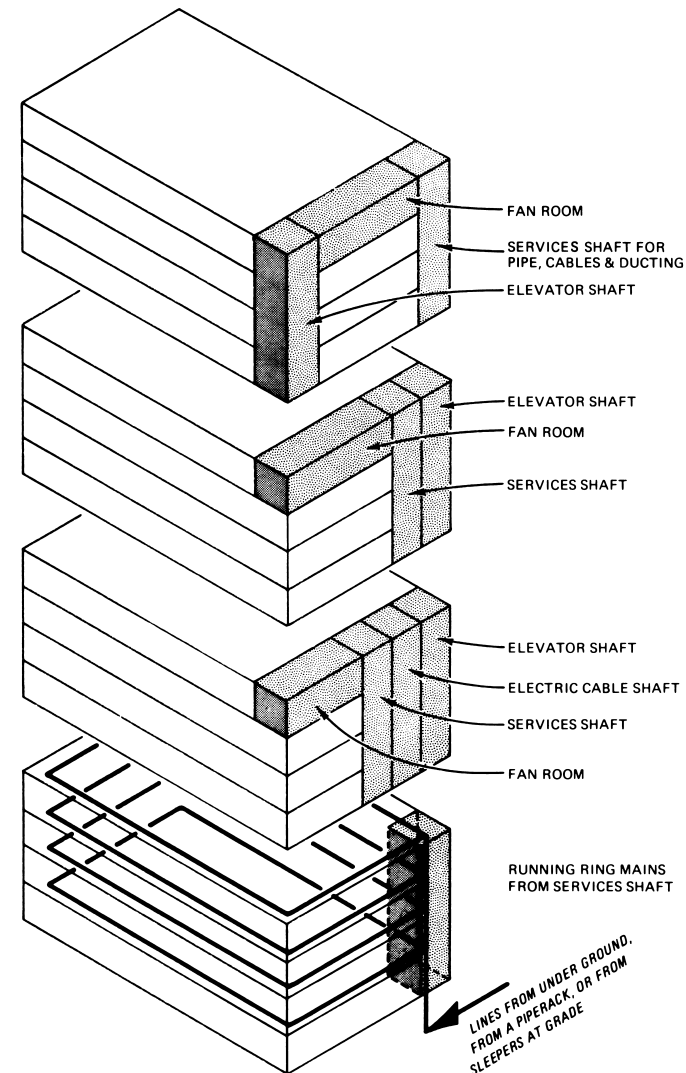
Different processes require different types of buildings. Some processes are best housed in single-story buildings with the process beginning at one end and finishing at the other end. Other processes are better assisted by gravity, starting at the top of a building or structure and finishing at or near grade.

## BUILDING SHAFTS FOR SERVICES

Provision of a services shaft or 'chase' in multi-storied buildings greatly simplifies arrangement of vertical piping, ducting and electric cables communicating between floors. Conceptual arrangements of services and elevator shafts, with fan room for air-conditioning and/or process needs, are shown in figure 6.50. Services shafts can be located in any position suitable to the process, and need not extend the whole height of the building.

### SUGGESTED BUILDING LAYOUTS

FIGURE 6.50



# STANDARDS AND CODES

## for Piping Systems, Pipe, Pipe Supports, Flanges, Gaskets, Fittings, Valves, Traps, Pumps, Vessels, Heat Exchangers, Symbols and Screwthreads

### WHAT ARE STANDARDS & CODES ?

#### 7.1

Standards are documents which establish methods for manufacturing and testing. Codes are documents which establish good design practices, including the factors of safety and efficiency. The documents are prepared and periodically updated by committees whose members may include representatives from industry, government, universities, institutes, professional societies, trade associations, and labor unions.

Proven engineering practices form the basis of standards and codes, so that they embody minimum requirements for selection of material, dimensions, design, erection, testing, and inspection, to ensure the safety of piping systems. Periodic revisions are made to reflect developments in the industry.

The terms 'standard' and 'code' have become almost interchangeable, but documents are termed codes when they cover a broad area, have governmental acceptance, and can form a basis for legal obligations. 'Recommendations' document advisable practice. 'Shall' in the wording of standards and codes denotes a requirement or obligation, and 'should' implies recommendation.

### FOUR REASONS FOR THEIR USE

#### 7.2

- (1) Items of hardware made according to a standard are interchangeable and of known dimensions and characteristics
- (2) Compliance with a relevant code or standard guarantees performance, reliability, quality, and provides a basis for contract negotiations, for obtaining insurance, etc.

- (3) A lawsuit which may follow a plant mishap, possibly due to failure of some part of a system, is less likely to lead to a punitive judgment if the system has been engineered and built to a code or standard
- (4) Codes often supply the substance for Federal, State, and Municipal safety regulations. However, the US Federal Government may, as needed, devise its own regulations, which are sometimes in the form of a code.

### WHO ISSUES STANDARDS ?

#### 7.3

The American Standards Association was founded in 1918 to authorize national standards originating from five major engineering societies. Previously a chaotic situation had arisen as many societies and trade associations had been issuing individual standards which sometimes overlapped. In 1967, the name of the ASA was changed to the USA Standards Institute, and in 1969 a second change was made, to American National Standards Institute. Standards previously issued under the prefixes 'ASA' and 'USASI' are now prefixed 'ANSI'.

Not all USA standards and codes are issued directly by the Institute. The American Society of Mechanical Engineers, the Instrument Society of America, and several other organizations issue standards and codes that apply to piping. Table 7.1 lists the principal sources.

ANSI makes available many such standards from other standards-issuing organizations ("sponsors"). Each of these standards is identified by the sponsor's designation (where one exists) preceded by ANSI's and the sponsor's acronym — for example, the ASME Code for chemical plant and

refinery piping is designated ANSI/ASME B31.3. If the sponsor does not provide a designation, ANSI assigns one. If an American Standards committee developed the standard, the committee designation is used.

The ANSI catalog is available from the American National Standards Institute, 1430 Broadway, New York, NY 10018

Other countries also issue standards. The British Standards Institution (BSI) in the UK, the Deutscher Normenausschuss (DIN) in Germany, and the Swedish national organization (SIS) issue many standards. Copies of foreign standards can be obtained directly, or from the American National Standards Institute.

## IDENTIFYING THE SOURCES OF STANDARDS 7.4

The tables in 7.5.6 give the initial letters of the standards-issuing organizations preceeding the number of the standard, thus: 'ASTM N28'. Table 7.1 includes the initials used in tables 7.3 thru 7.14, and gives the full titles of the organizations. (Table 7.1 is not a comprehensive listing.)

**PRINCIPAL ORGANIZATIONS  
ISSUING STANDARDS**

**TABLE 7.1**

| INITIALS   | FULL TITLE OF ORGANIZATION   |
|--|--|
| AIA  | American Insurance Association *   |
| ANSI   | American National Standards Institute †                                      |
| API  | American Petroleum Institute   |
| ASME   | American Society of Mechanical Engineers                                     |
| ASTM   | American Society for Testing and Materials                                   |
| AWS  | American Welding Society   |
| AWWA   | American Waterworks Association  |
| FCI  | Fluid Controls Institute   |
| GSA  | General Service Administration   |
| ISA  | Instrument Society of America  |
| MSS  | Manufacturers' Standardization Society of the<br>Valve and Fittings Industry |
| NFPA   | National Fire Protection Association   |
| PFI  | Pipe Fabrication Institute   |
| USDC   | United States Department of Commerce   |
| *Standards formerly issued by Underwriters' Laboratories Inc.<br>†Formerly, United States of America Standards Institute, and<br>American Standards Association. |  |

## PRINCIPAL DESIGN-ORIENTATED CODES 7.5

### ANSI CODE B31 7.5.1

The most important code for land-based pressure-piping systems is ANSI B31. Parts of this code which apply to various types of plant piping are listed in table 7.2.

**ANSI CODE B31 FOR PRESSURE PIPING**

**TABLE 7.2**

| TITLE  | SECTION   | APPLICATION   |
|--|-----------|---|
| Corrosion Control                                | B31 Guide | Guidelines for protecting B31 piping systems from corrosion   |
| Power Piping                                     | B31.1-    | Piping for industrial plants and marine applications  |
| Chemical Plant and Petroleum Refinery Piping     | B31.3-    | Design of chemical and petrochemical plants and refineries processing chemicals and hydrocarbons, water and steam |
| Liquid Petroleum Transportation                  | B31.4-    | Liquid transportation systems for hydrocarbons, LPG, anhydrous ammonia and alcohols                               |
| Refrigeration piping                             | B31.5-    | Principally describes the piping of packaged units  |
| Gas Transmission and Distribution Piping Systems | B31.8-    | Principally describes overland conveyance of fuel gases and feedstock gases                                       |
| Building Services Piping Code                    | B31.9-    | High-pressure commercial/sanitary piping  |
| Slurry Transportation Piping                     | B31.11-   | Design, construction, inspection, security requirements of slurry piping systems                                  |

### AMERICAN PETROLEUM INSTITUTE'S STANDARD 2510 7.5.2

This Standard covers design and construction of liquefied petroleum gas installations at marine and pipeline terminals, natural gas processing plants, refineries, petroleum plants and tank farms

The two following codes are not directly related to piping, but frequently are involved in the piping designer's work:

### API 510, PRESSURE VESSEL INSPECTION CODE 7.5.3

This code applies to repairs and alterations made to vessels in petro-chemical service constructed to the former API-ASME Code for Unfired Pressure Vessels for Petroleum Liquids and Gases, Section 8 of the ASME Boiler and Pressure Vessel Code, and to other vessels.

### ASME BOILER & PRESSURE VESSEL CODE 7.5.4

The ASME Boiler and Pressure Vessel Code is mandatory in many states with regard to design, material specification, fabrication, erection, and testing procedures. Compliance is required in the USA and Canada to qualify for insurance. The Code consists of the following eleven sections:

#### ASME BOILER & PRESSURE VESSEL CODE

#### section

|   |    |
|---|----|
| Power boilers . . . . .   | 1  |
| Material specifications . . . . .   | 2  |
| Nuclear power plant components . . . . .                                    | 3  |
| Heating boilers . . . . .   | 4  |
| Nondestructive examination . . . . .  | 5  |
| Recommended rules for care and operation of heating boilers . . . . .       | 6  |
| Recommended rules for care of power boilers . . . . .                       | 7  |
| Pressure vessels . . . . .  | 8  |
| Welding qualifications . . . . .  | 9  |
| Fiberglass-reinforced plastic pressure vessels . . . . .                    | 10 |
| Rules for inservice inspection of nuclear reactor coolant systems . . . . . | 11 |

## CODES FOR MARINE PIPING

## 7.5.5

Requirements for merchant and naval vessels are contained in the following standards:

- (1) **American Bureau of Shipping:** 'Rules for building and classing vessels'
- (2) **Lloyds' Register of Shipping:** 'Rules'
- (3) **US Coast Guard:** 'Marine engineering regulations and material specifications'
- (4) **US Navy, Bureau of Ships:** 'General specifications for building naval vessels', 'General machinery specifications'

## SELECTED STANDARDS

## 7.5.6

The following tables are not comprehensive: a selection has been made from standards relating to piping design and technology. Sources of these standards may be found from table 7.1. Addresses of the issuing organizations may be found from the current edition of 'Encyclopedia of associations: Vol 1, National organizations of the United States' (Gale Research Company).

## STANDARDS FOR SYMBOLS AND DRAFTING

TABLE 7.3

|                         |   |  |
|-------------------------|---|--|
| Piping                  | Graphic symbols for pipe fittings, valves and piping<br>Graphic symbols for plumbing fixtures<br>Graphic symbols for fluid power diagrams<br>Fluid power diagrams   | ANSI/ASME Y32.2.3<br>ANSI Y32.4<br>ANSI Y32.10<br>ANSI Y14.7                         |
| Process Engineering     | Graphic symbols for process flow diagrams in petroleum and chemical industries<br><br>Letter symbols for chemical engineering<br>Letter symbols for hydraulics  | ANSI Y32.11<br><br>ANSI Y10.12<br>ANSI Y10.2   |
| Instrumentation         | Instrumentation symbols and identification  | ISA S5.1   |
| Welding                 | Symbols for welding and nondestructive testing  | AWS A2.4-79  |
| Heating and Ventilating | Graphic symbols for heating, ventilating and air conditioning   | ANSI Y32.2.4   |
| Electrical              | Electrical and electronics diagrams<br>Graphic symbols for electrical wiring and layout diagrams used for architecture and building construction  | ANSI Y14.15<br><br>ANSI Y32.9  |
| Drafting                | Drawing sheet size and format<br>Line conventions, sectioning and lettering<br>Multi and sectional view drawings<br>Pictorial drawing<br>Dimensioning and tolerancing for engineering drawings<br>Screw thread representation | ANSI Y14.1<br>ANSI Y14.2<br>ANSI Y14.3<br>ANSI Y14.4<br><br>ANSI Y14.5<br>ANSI Y14.6 |
| Safety                  | Symbols for fire fighting operations  | NFPA 178   |

## STANDARDS FOR PIPING (DESIGN AND FABRICATION)

TABLE 7.4

|              |   |                                     |
|--------------|---|-------------------------------------|
| Design       | Power piping code (refer to Table 7.2)  | ASME B31                            |
| Drafting     | Method for dimensioning piping assemblies<br>Minimum length and spacing for welded nozzles  | PFI ES-2<br>PFI ES-7                |
| Fabrication  | Buttwelding ends for pipe, valves, flanges and fittings<br>Internal machining and solid machined backing rings for circumferential back-welds<br>Fabricating tolerances | ASME B16.25<br>PFI ES-1<br>PFI ES-3 |
| Testing      | Hydrostatic testing of fabricated piping  | PFI ES-4                            |
| Cleaning     | Cleaning of fabricated piping   | PFI ES-5                            |
| Color Coding | Scheme for the identification of piping systems<br>Recommended practice for color coding of piping materials  | ANSI A13.1<br>PFI ES-22             |

## PRINCIPAL STANDARDS FOR PIPE

TABLE 7.5

|                  |   |  |
|------------------|---|--|
| Steel or Iron    | Specification for welded and seamless steel pipe<br>Specification for seamless carbon-steel pipe for high-temperature service<br>Specification for electric-fusion(arc)-welded steel pipe, NPS 16 and over<br>Specification for electric-resistance-welded steel pipe<br>Specification for seamless and welded austenitic stainless steel pipe<br>Specification for seamless ferritic alloy-steel pipe for high-temperature service<br>Specification for seamless carbon-steel pipe for atmospheric and lower temperatures<br>Specification for line pipe (5L and 5LX)  | ASTM A53<br>ASTM A106<br>ASTM A134<br>ASTM A135<br>ASTM A312<br>ASTM A335<br>ASTM A524<br>API 5L   |
|                  | Welded and seamless wrought-steel pipe<br>Stainless steel pipe  | ASME B36.10M<br>ANSI B36.19  |
|                  | Ductile iron pipe, centrifugally cast, in metal molds or sand-lined molds for water and other liquids   | ANSI/AWWA51 C151/A21.51  |
|                  | Ductile iron pipe, centrifugally cast, in metal molds or sand-lined molds for gas   | ANSI A21.52  |
| Nonferrous Alloy | Specification for aluminum and aluminum-alloy seamless pipe and extruded seamless tube<br>Specification for seamless copper pipe, standard sizes<br>Specification for seamless red brass pipe, standard sizes<br>Specification for seamless copper alloy pipe and tube<br>Specification for seamless nickel pipe and tube   | ASTM B241<br>ASTM B42<br>ASTM B43<br>ASTM B315<br>ASTM B161  |
| Plastics         | Specification for cellulose acetate butyrate (CAB) plastic pipe, SCH 40<br>Specification for acrylonitrile-butadiene-styrene (ABS) plastic pipe, SCH 40 and 80<br>Specification for polyvinyl chloride (PVC) plastic pipe, SCH 40, 80 and 120<br>Specification for polyethylene (PE) plastic pipe, SCH 40<br>Specification for acrylonitrile-butadiene-styrene (ABS) plastic pipe (SDR-PR)<br>Specification for polyvinyl chloride (PVC) plastic pipe (SDR series)<br>Specification for polyethylene (PE) plastic pipe (SIDR-PR) based on controlled inside diameter<br>Polyvinyl chloride (PVC) pressure pipe for water NPS 4 thru NPS 12<br>Polyethylene (PE) pressure pipe, tubing and fittings for water NPS 1/2 thru NPS 3<br>Polybutylene (PB) pressure pipe, tubing and fittings for water NPS 1/2 thru NPS 3<br>Glass fiber reinforced pipe | ASTM D1503<br>ASTM D1527<br>ASTM D1785<br>ASTM D2104<br>ASTM D2282<br>ASTM D2241<br>ASTM D2239<br>AWWA C900<br>AWWA C901<br>AWWA C902<br>AWWA C950 |

## STANDARDS FOR HANGERS AND SUPPORTS

TABLE 7.6

|             |   |           |
|-------------|---|-----------|
| Application | Pipe hangers and supports - selection and application         | MSS SP-69 |
| Production  | Pipe hangers and supports - materials, design and manufacture | MSS SP-58 |

## STANDARDS FOR GASKETS

TABLE 7.7

|             |  |  |
|-------------|--|--|
| Metallic    | Ring-joint gaskets and grooves for steel pipe flanges<br>Metallic gaskets for raised-face pipe flanges and flanged connections (double-jacket corrugated and spiral-wound)   | ASME B16.20<br>API 601                           |
| Nonmetallic | Nonmetallic flat gaskets for pipe flanges<br>Rubber gasket joints for ductile-iron and gray-iron pressure pipe and fittings<br>Gasketed joints for ductile iron and gray iron pressure pipe and fittings for fire protection service<br>Standard specification for dense elastomer silicone rubber gaskets and accessories | ASME B16.21<br>AWWA C111<br>UL 194<br>ASTM C1115 |

## STANDARDS FOR FITTINGS (Also, see Table 7.10)

TABLE 7.8

|                 |   |   |
|-----------------|---|---|
| Steel Fittings  | Factory-made wrought-steel buttwelding fittings<br>Wrought-steel buttwelding short-radius elbows and returns<br>Forged-steel fittings, socketwelding and threaded<br>Carbon steel pipe unions, socketwelding & threaded<br>Factory-made buttwelding fittings for class 1 nuclear piping applications  | ASME B16.9<br>ASME B16.28<br>ASME B16.11<br>MSS-SP-83<br>MSS SP-87      |
| Stainless Steel | Wrought stainless steel buttwelding fittings including reference to other corrosion resistant materials   | MSS SP-43   |
| Malleable Iron  | Malleable iron threaded fittings  | ASME B16.3  |
| Cast Iron       | Cast-iron threaded fittings, class 125 and 250<br>Cast-iron threaded drainage fittings  | ASME B16.4<br>ANSI B16.12   |
| Ductile Iron    | Ductile-iron fittings, NPS 3 thru NPS 24 for gas<br>Ductile-iron pipe flanges and flanged fittings  | ANSI A21.14<br>ASME B16.42  |
| Ferrous         | Ferrous pipe plugs, bushings and locknuts with pipe threads   | ANSI B16.14   |
| Copper Alloy    | Cast bronze threaded fittings, class 125 and 250<br>Cast copper alloy solder joint pressure fittings<br>Bronze pipe flanges and flanged fittings, class 150 and 300<br>Cast copper alloy solder joint fittings for Solvent drainage systems<br>Wrought copper and wrought copper alloy solder-joint drainage fittings for Solvent drainage fittings | ASME B16.15<br>ANSI B16.18<br>ANSI B16.24<br>ASME B16.32<br>ANSI B16.43 |
| Plastics        | Specification for socket type acrylonitrile-butadiene-styrene (ABS) plastic pipe fittings SCH 40<br>Specification for socket type polyvinyl chloride (PVC) plastic pipe fittings SCH 80   | ASTM D2468<br>ASTM D2467  |

## STANDARDS FOR VALVES

TABLE 7.9

|              |   |   |
|--------------|---|---|
| General      | Face-to-face and end-to-end dimensions of ferrous valves, classes 125 thru 2500 (gate, globe, plug ball, and check valves)<br>Manually operated metallic gas valves for use in gas piping systems up to 125 PSIG (sizes NPS 1/2 thru NPS 2)<br>Valves, flanged and buttwelding end -- steel, nickel alloy, and other special alloys<br>Specification for pipeline valves (steel gate, plug, ball and check valves)<br>Earthquake activated automatic gas shutoff system | ANSI B16.10<br>ANSI B16.33<br>ASME B16.34<br>API 6D<br>AGA Z21.70             |
| Gate Valves  | Steel venturi gate valves, flanged and butt-welding ends<br>Steel gate valves, flanged and butt-welding ends<br>Compact steel gate valves<br>Class 150 cast, corrosion-resistant flanged end gate valves<br>Ductile-iron gate valves, flanged ends<br>Gate valves, NPS 3 thru NPS 48, for water and sewage systems<br>Resilient seated gate valves, NPS 3 thru NPS 12, for water and sewage systems   | API 597<br>API 600<br>API 602<br>API 603<br>API 604<br>AWWA C500<br>AWWA C509 |
| Butterfly    | Butterfly valves<br>Rubber seated butterfly valves<br>Butterfly valves, lug-type and wafer-type   | MSS SP-67<br>AWWA C504<br>API 609   |
| Check Valves | Swing check valves for waterworks service, NPS 2 thru NPS 24<br>Wafer check valves<br>Cast-iron swing check valves, flanged and threaded ends   | AWWA C508<br>API 594<br>MSS SP-71   |
| Ball Valves  | Ball valves-flanged and butt-welding ends<br>Ball valves with flanged or buttwelding ends for general service<br>Ball valves, NPS 6 thru NPS 48   | API 608<br>MSS SP-72<br>AWWA C507   |
| Relief       | Safety and relief valves<br>Flanged steel safety-relief valves  | ASME PTC25.3<br>API 526   |
| Control      | Control valve manifold designs -- recommended practice<br>Face-to-face dimensions for flanged globe-style control valve bodies (ANSI classes 125, 150, 250, 300 and 600)<br>Face-to-face dimensions for flangeless control valves (ANSI classes 150, 300 and 600)<br>Face-to-face dimensions for butt-weld-end globe-style control valves (ANSI class 4500)   | ISA RP75.06<br>ISA S75.03<br>ISA S75.04<br>ISA S75.14                         |

## STANDARDS FOR UNFIRED VESSELS AND TANKS

TABLE 7.10

|                             |   |   |
|-----------------------------|---|---|
| Pressure Vessels            | Boiler and Pressure Vessel Code, section VIII, "Pressure vessels"   | ASME Code   |
| Low Pressure Vessels        | Requirements for tank containers for liquids and gases<br>Specification for bolted tanks for storage of production liquids<br>Specification for field-welded tanks for storage of production liquids<br>Specification for shop-welded tanks for storage of production liquids<br>Recommended rules for design and construction of large welded low-pressure storage tanks<br>Welded steel tanks for oil storage<br>Specification for welded aluminum alloy storage tanks<br>Steel aboveground tanks for flammable and combustible liquids<br>Safety standard for steel inside tanks for oil-burner fuel<br>Steel underground tanks for flammable and combustible liquids<br>Factory-coated bolted steel tanks for water storage<br>Welded steel tanks for water storage | ASME MH5.1.3<br>API 12B<br>API 12D<br>API 12F<br>API 620<br>API 650<br>ANSI B96.1<br>UL 142<br>UL 80<br>UL 58<br>AWWA D103-80<br>AWWA D100-79 |
| Lined Vessels               | Design, fabrication and surface finish of metal tanks and vessels to be lined for chemical service  | NACE RP-01  |
| Calibration                 | Method for liquid calibration of tanks<br>Method for measurement and calibration of horizontal tanks<br>Method for measurement and calibration of spheres and spheroids<br>Method for measurement and calibration of upright cylindrical tanks  | ASTM D1406<br>ASTM D1410<br>ASTM D1408<br>ASTM D1220  |
| Venting and Flame Arresters | Venting atmospheric and low-pressure storage tanks (refrigerated and nonrefrigerated)<br>Flame arresters for vents of tanks storing petroleum products<br>Flame arresters for use on vents of storage tanks for petroleum oil and gasoline  | API 2000<br>API 2210<br>UL 525  |

## STANDARDS FOR FLANGES

TABLE 7.11

|                   |   |   |
|-------------------|---|---|
| Steel Flanges     | Pipe flanges and flanged fittings   | ANSI B16.5  |
|                   | Steel orifice flanges   | ANSI B16.36                                       |
|                   | Large diameter carbon-steel flanges (NPS 26-60, class 75, 150, 300, 400, 600 and 900)<br>Steel pipeline flanges<br>High-pressure chemical industry flanges and threaded stubs for use with lens gaskets<br>Steel flanges for waterworks service, NPS 4 thru NPS 144 | API 605<br>MSS SP-44<br>MSS SP-65<br>AWWA C207-78 |
| Cast-iron Flanges | Cast-iron pipe flanges and flanged fittings<br>Class 150LW corrosion-resistant cast flanges and flanged fittings  | ASME B16.1<br>MSS SP-51                           |
| Ductile Iron      | Ductile iron flanges and flanged fittings, class 150 and 300  | ASME B16.42                                       |
| Finishing         | Finishes for contact faces of pipe flanges and connecting-end flanges of valves and fittings  | MSS SP-6  |

## STANDARDS FOR SCREW THREADS FOR PIPING, NUTS AND BOLTS TABLE 7.12

|                      |   |  |
|----------------------|---|--|
| General              | Unified inch screw threads (UN & UNR thread form)<br>Pipe threads, general purpose (inch)<br>Nomenclature, definitions and letter symbols for screw threads   | ANSI B1.1<br>ANSI / ASME B1.20.1<br>ASME B1.7M |
| Dryseal Pipe Threads | Dryseal pipe threads (inch)<br>Dryseal pipe threads (metric translation of ANSI B1.20.3)  | ANSI B1.20.3<br>ANSI B1.20.4                   |
| Hose Threads         | Hose coupling screw threads for all connections having nominal hose (inside) diameters of 1/2, 5/8, 3/4, 1, 1 1/4, 1 1/2, 2, 2 1/2, 3, 3 1/2 and 4 inches (except fire hose)<br>Screw threads and gaskets for fire hose connections | ASME B1.20.7<br>NFPA 1963-85                   |

**STANDARDS FOR HEAT EXCHANGERS AND HEATERS**
**TABLE 7.13**

|                           |   |              |
|---------------------------|---|--------------|
| Shell-and-Tube Exchangers | Tubular heat exchangers in chemical process service   | ANSI B78.1   |
|                           | Shell-and-tube exchangers for general refinery services   | API 660      |
|                           | Specification for seamless cold-drawn low-carbon steel heat exchanger and condenser tubes                   | ASTM A179/M  |
|                           | Specification for seamless cold-drawn intermediate alloy steel heat exchanger and condenser tubes           | ASTM A199/M  |
|                           | Specification for seamless ferritic and austenitic alloy steel boiler, superheater and heat-exchanger tubes | ASTM A213/M  |
|                           | Specification for seamless nickel and nickel alloy condenser and heat exchanger tubes                       | ASTM B163    |
| Air Exchangers            | Air cooled heat exchangers for general refinery service   | API 661      |
|                           | Winterizing of air-cooled heat exchangers   | API 632      |
| Heaters                   | Closed feedwater heaters  | ASME PTC12.1 |
|                           | Performance test code -- air heaters  | ASME PTC4.3  |
|                           | Desuperheater/water heaters   | ARI 470-80   |

**STANDARDS FOR PRIME MOVERS**
**TABLE 7.14**

|                                      |  |             |
|--------------------------------------|--|-------------|
| General                              | Specification for pumping units  | API 11E     |
|                                      | Positive displacement pumps -- reciprocating                                     | API 674     |
|                                      | Positive displacement pumps -- controlled volume                                 | API 675     |
|                                      | Pumps for oil burning appliances   | UL 343      |
| Centrifugal Pumps                    | Centrifugal pumps  | ASME PTC8.2 |
|                                      | Specifications for horizontal end suction centrifugal pumps for chemical process | ASME B73.1M |
|                                      | Specifications for vertical in-line centrifugal pumps for chemical process       | ASME B73.2M |
|                                      | Centrifugal pumps for general refinery service                                   | API 610     |
| Positive Displacement                | Displacement pumps (performance test code)                                       | ASME PTC7.1 |
|                                      | Reciprocating steam-driven displacement pumps                                    | ASME PTC7   |
|                                      | Displacement compressors, vacuum pumps and blowers                               | ASME PTC9   |
| Compressors, exhausters and ejectors | Safety standard for compressors for process industries                           | ASME B19.3  |
|                                      | Installation of blowers and exhaust systems                                      | NFPA 91     |
|                                      | Centrifugal compressors for general refinery services                            | API 617     |
|                                      | Compressors and exhausters - performance test code                               | ASME PTC10  |
|                                      | Ejectors - performance test code   | ASME PTC24  |

# ABBREVIATIONS for Piping Drawings and Industrial Chemicals

ABBREVIATIONS USED ON PIPING DRAWINGS, DOCUMENTS, Etc.

8.1

## A

|      |  |
|------|--|
| A    | (1) Air<br>(2) Absolute                    |
| ABS  | Absolute                                   |
| AGA  | American Gas Association                   |
| AISI | American Iron and Steel Institute          |
| ANSI | American National Standards Institute      |
| API  | American Petroleum Institute               |
| ASTM | American Society for Testing and Materials |
| AWS  | American Welding Society                   |
| AWWA | American Waterworks Association            |

## B

|      |   |
|------|---|
| BBL  | Barrel  |
| BC   | Bolt circle   |
| BLE  | Beveled large end   |
| BLK  | Black   |
| BLVD | Beveled   |
| BOP  | Bottom [of outside] of pipe. Used for pipe support location |
| BS   | British Standard  |
| BTU  | British thermal unit  |
| BW   | (1) Butt weld<br>(2) Butt welded                            |

## C

|      |   |
|------|---|
| C    | (1) Centigrade, or Celsius<br>(2) Condensate  |
| CENT | Centigrade  |
| CFM  | Cubic feet per minute   |
| CHU  | Centigrade heat unit  |
| CI   | Cast iron   |
| CM   | Centimeter  |
| Cr   | Chromium  |
| CS   | (1) Carbon steel<br>(2) Cold spring   |
| CSC  | Car-sealed closed. Denotes a valve to be locked in the closed position under all circumstances other than repair to adjacent piping |
| CSO  | Car-sealed open. See CSC  |
| CTR  | Center  |
| CU   | Cubic   |

## D

|     |   |
|-----|---|
| DEG | Degree                                    |
| DIA | Diameter                                  |
| DIN | Deutsche Industrie Norm [German standard] |
| DO  | Drawing office                            |
| DRG | Drawing. [Not preferred]                  |
| DWG | Drawing                                   |

## E

|     |                            |
|-----|----------------------------|
| E   | East                       |
| ECN | Engineering change number  |
| EFW | Electric-fusion-welded     |
| ELL | Elbow                      |
| ERW | Electric-resistance-welded |

## F

|       |   |
|-------|---|
| F     | Fahrenheit  |
| F&D   | Faced and drilled   |
| FAHR  | Fahrenheit  |
| FBW   | Furnace-butt-welded   |
| FCN   | Field change number   |
| FD&SF | Faced, drilled and spot-faced   |
| FE    | Flanged end   |
| FF    | (1) Flat face(d)<br>(2) Full face [of gasket]<br>(3) Flange face [dimensioning]   |
| FLG   | Flange  |
| FLGD  | Flanged   |
| FOB   | (1) Flat on bottom. [Indicates orientation of eccentric reducer]<br>(2) Freight on board. [Indicates location of supply of vendor's freight at the stated price]<br>(3) Free on board. [Indicates location of supply of vendor's freight] |
| FOT   | Flat on top. [Indicates orientation of eccentric reducer]   |
| FRP   | [Glass-] fiber reinforced pipe  |
| FS    | Forged steel  |
| FW    | Field weld  |

## G

|      |                                  |
|------|----------------------------------|
| G    | (1) Gas<br>(2) Grade<br>(3) Gram |
| GAL  | Gallon                           |
| GALV | Galvanized                       |
| GPH  | Gallons per hour                 |
| GPM  | Gallon per minute                |

## H

|     |                            |
|-----|----------------------------|
| H   | (1) Horizontal<br>(2) Hour |
| HEX | Hexagon(al)                |
| Hg  | Mercury                    |
| HPT | Hose-pipe thread           |
| HR  | Hour                       |

## I

|    |                  |
|----|------------------|
| IE | Invert elevation |
|----|------------------|

|      |  |
|------|--|
| ID   | (1) Inside diameter<br>(2) Internal diameter |
| IMP  | Imperial. [British unit]                     |
| IPS  | Iron pipe size                               |
| IS   | Inside screw. [Of valve stem]                |
| ISO  | Isometric drawing                            |
| IS&Y | Inside screw and yoke                        |

## K

|    |                                 |
|----|---------------------------------|
| K  | Kilo, times one thousand, x1000 |
| kg | Kilogram                        |

## L

|       |                         |
|-------|-------------------------|
| L     | Liquid                  |
| LB,Lb | Pound weight            |
| LT    | Light-wall [of Pipe]    |
| LR    | Long radius. [Of Elbow] |

## M

|      |   |
|------|---|
| M    | (1) Meter<br>(2) Mega, times one million, 1 000 000. [On old drawings, x1000] |
| MACH | Machined  |
| MATL | Material  |
| MAWP | Maximum allowable working pressure  |
| MAX  | Maximum   |
| MCC  | Motor control center  |
| M/C  | Machine   |
| MFR  | Manufacturer  |
| MI   | Malleable iron  |
| MIN  | (1) Minimum<br>(2) Minute. [Of time]  |
| mm   | Millimeter  |
| Mo   | Molybdenum  |
| MSS  | Manufacturers' Standardization Society of the Valve and Fittings Industry     |

## N

|      |  |
|------|--|
| N    | North  |
| NC   | Normally closed                                    |
| NEMA | National Electrical Manufacturers' Assn.           |
| Ni   | Nickel   |
| NIC  | Not in contract                                    |
| NO   | Normally open                                      |
| NPSC | 2.5.5  |
| NPSF | 2.5.5  |
| NPSH | (1) Net positive suction head.[3.2.1]<br>(2) 2.5.5 |
| NPSI | 2.5.5  |
| NPSL | 2.5.5  |
| NPSM | 2.5.5  |

NPT National pipe thread  
 NPTF 2.5.5  
 NRS Non-rising stem. [Of valve]

## O

O Oil  
 OD Outside diameter  
 OS Outside screw. [Valve stem]  
 OS&Y Outside screw and yoke. [Valve stem]

## P

P&ID Piping and instrumentation diagram  
 PBE Plain both ends. [Swage, etc.]  
 PE Plain end. [Pipe, etc.]  
 PFI Pipe Fabrication Institute  
 POE Plain one end. [Nipple, etc.]  
 PS (1) Pipe support. [Anchor, guide or shoe, or items combined to form the support]  
 (2) Pre-spring  
 PSI Pound [weight] per square inch. [Pressure]  
 PSIA Pound per square inch absolute  
 PSIG Pound per square inch gage

## R

RED Reducing  
 RF Raised face  
 RJ Ring joint  
 RPM Revolutions per minute  
 RS Rising stem. [Of valve]

## S

S (1) South  
 (2) Steam

SAE Society of Automotive Engineers  
 SCH Schedule. [Of pipe]  
 SCRD Screwed  
 SF Spot-faced  
 SKT Socket  
 SMLS Seamless  
 Si Silicon  
 SO Slip-on  
 SP (1) Sample point  
 (2) Standard practice. [MSS term]

SR Short radius. [Of elbow]  
 SST Stainless steel  
 ST Steam trap  
 STM Steam  
 STD Standard  
 STR Straight  
 SW Socket welding  
 SWG Swage  
 SWG / Swaged nipple  
 NIPP )  
 SWP Steam working pressure

## T

T (1) Temperature  
 (2) Trap  
 T&C Threaded and coupled. [Pipe]  
 TEMA Tubular Exchanger Manufacturers' Assn.  
 TGT Tangent  
 TOE Threaded one end. [Nipple or Swage]  
 TOS Top of support  
 TPI Threads per inch  
 TSE Threaded small end  
 TYP Typical. [Used to avoid redrawing similar arrangements]

## U

UNC 2.6.3  
 UNF 2.6.3  
 UNS 2.6.3

## V

V (1) Vertical  
 (2) Vanadium

## W

W (1) West  
 (2) Water  
 WGT Weight  
 WLD Weld(ed)  
 WN Welding neck  
 WOG Water, oil and gas  
 WP (1) Workpoint or reference point  
 (2) Markings with this prefix designate certain steels and are used on pipe, fittings and plate. Example: 'WPB' marked on forged fittings denotes A181 grade 2. Refer to ASME SA-234, tables 1 and 2.

WT Weight

## X

XH Extra-heavy. [See Index]  
 XS Extra-strong  
 XXS Double-extra-strong

## OTHER

⌒ Centerline  
 ∅ Diameter

## ABBREVIATIONS FOR COMMERCIAL CHEMICALS

8.2

| ABBREVIATION | CHEMICAL NAME  | AREA OF USE | D        |  |             |
|--------------|--|-------------|----------|--|-------------|
| <b>A</b>     |  |             | DAP      | Diammonium phosphate                           | Agriculture |
| ADA          | Acetone dicarboxylic acid                            | Drugs       | DCO      | Dehydrated castor oil                          | Paint       |
| AEA          | Air-entraining agent                                 | Concrete    | DMC      | Dimethylammonium dimethyl carbamate            | Refining    |
| ANW          | 83% ammonium nitrate in water                        |             | DMF      | Dimethyl formamide                             |             |
| <b>B</b>     |  |             | DMU      | Dimethylurea                                   |             |
| BAP          | Benzyl para-amino phenol                             | Fuel        | DNA      | Dinonyladipate                                 | Plastics    |
| BHA          | Butylated hydroxyanisole                             | Food        | DNM      | Dinonyl maleate                                | Plastics    |
| BHC          | Benzene hexachloride                                 | General     | DNP      | Dinonyl phthalate                              | Plastics    |
| BHT          | Butylated hydroxytoluene                             | Food        | DNT      | Dinitrotoluene                                 | Explosives  |
| BOV          | 77-78% sulfuric acid ('blown oil of vitreol')        | General     | DOP      | Diocetyl phthalate                             | Plastics    |
| BzH          | Benzaldehyde   | General     | DOV      | 96% sulfuric acid ('distilled oil of vitreol') | General     |
| BzOH         | Benzoic acid   | General     | DSP      | Disodium phosphate                             | General     |
| <b>C</b>     |  |             | DTBP     | Ditertiary-butyl peroxide                      | Plastics    |
| CO           | Carbon monoxide                                      |             | DVB      | Divinyl benzene                                | Plastics    |
| COV          | 95-96% sulfuric acid ('concentrated oil of vitreol') | General     | DPG      | Diphenyl guanidine                             | Rubber      |
| CO2          | Carbon dioxide                                       | General     | DOPA     | 3,4-dihydroxyphenylaniline                     | Rubber      |
|              |  |             | <b>E</b> |  |             |
|              |  |             | EA       | Ethylidene aniline                             | Rubber      |
|              |  |             | EDTA     | Ethylene diamine tetra-acetic acid             | Food        |

| ABBREVIATION     | MEANING  | AREA OF USE            |
|------------------|--|------------------------|
| <b>F</b>         |  |                        |
| FA               | Furfuryl alcohol   | General                |
| FGAN             | Ammonium nitrate   | Agriculture            |
| FPA              | Fluorophosphoric acid  |                        |
| FREON            | One of a large number of chloro- or fluoro- substituted hydrocarbons | Refrigeration, General |
| <b>H</b>         |  |                        |
| HCN              | Hydrocyanic acid, hydrogen cyanide                                   | Plating                |
| HET              | Hexa-ethyl tetraphosphate  | Agriculture            |
| HMDT             | Hexamethylene triperoxide  |                        |
| HMT              | Hexamethylene tetramine  |                        |
| HNH              | Mannitol hexanitrate   | Explosives             |
| HTP              | 100% hydrogen peroxide ('high test peroxide'),                       | Rocketry, General      |
|                  | Branched aliphatic alcohols of high b.pt.                            |                        |
| H <sub>2</sub> O | Water  |                        |
| <b>I</b>         |  |                        |
| IMS              | Commercial ethyl alcohol (Brit.)                                     | General                |
| IPA              | Isophthalic acid   |                        |
| IPC              | Isopropyl n-phenyl carbonate   |                        |
| IPS              | Isopropyl alcohol (Shell Oil Co.)                                    | General                |
| <b>L</b>         |  |                        |
| LOX              | Liquid oxygen  | Rocketry               |
| LPC              | Lauryl pyridinium chloride   | Soaps                  |
| LPG              | Liquefied petroleum gases, mainly butane and propane                 | Fuel                   |
| <b>M</b>         |  |                        |
| MBMC             | Monotertiary butyl-methyl-cresol                                     | General                |
| MEK              | Methyl-ethyl-ketone  | Paint, General         |
| MEP              | 2-methyl, 5-ethyl pyridine   |                        |
| MIBC             | Methyl isobutyl carbinol   |                        |
| MIBK             | Methyl-isobutyl-ketone   |                        |
| MNA              | Methyl-nonyl acetaldehyde  |                        |
| MNPT             | m-nitro p-toluidine  |                        |
| MNT              | Mononitro toluene  | Explosives             |
| MSG              | Monosodium glutamate   | Food                   |
| <b>N</b>         |  |                        |
| NBA              | n-bromacetamide  |                        |
| NBS              | n-bromosuccinamide   |                        |
| NCA              | n-chloracetamide   |                        |
| NCS              | n-chlorosuccinamide  |                        |
| NH powder        | Explosive powder   |                        |
| N <sub>2</sub>   | Nitrogen   |                        |

|                 |  |                |
|-----------------|--|----------------|
| <b>O</b>        |  |                |
| OMPA            | Octamethyl pyrophosphoramide             | Agriculture    |
| ONB             | o-nitrobiphenyl                          | Plastics       |
| OPE             | Octylphenoxyethanol                      | Refining       |
| O <sub>2</sub>  | Oxygen                                   | General        |
| O <sub>3</sub>  | Ozone                                    |                |
| <b>P</b>        |  |                |
| PAS             | p-aminosalicylic acid                    | Drugs          |
| PB              | Polybutene                               | Plastics       |
| PBNA            | Phenyl beta-naphthylamine                | Rubber         |
| PDB             | p-dichlorobenzene                        | Agriculture    |
| PE              | Penta-erythritol                         |                |
| PETN            | Penta-erythritol tetranitrate            | Explosives     |
| PTFE            | Polytetrafluorethylene                   | Plastics       |
| PVA or PVAL     | Polyvinyl alcohol                        |                |
| PVAc            | Polyvinyl acetate                        |                |
| PVB             | Polyvinyl butyrol                        |                |
| PVC             | Polyvinyl chloride                       |                |
| PVM             | Polyvinyl methyl-ether                   |                |
| <b>R</b>        |  |                |
| RNV             | Sulfuric acid ('refined oil of vitreol') | General        |
| <b>S</b>        |  |                |
| S               | Sulfur                                   | General        |
| SAP             | Sodium acid pyrophosphate                |                |
| SDA             | Specially denatured alcohol              | General        |
| SO <sub>2</sub> | Sulfur dioxide                           | General        |
| <b>T</b>        |  |                |
| TCA             | Sodium tetrachloracetate                 | Agriculture    |
| TCE             | 1,1,1-trichlorethane                     | Dry cleaning   |
| TCP             | Tricresyl phosphate                      | Fuel, Plastics |
| TEG             | Triethylene glycol                       | Refining       |
| TEL             | Tetraethyl lead                          | Fuel           |
| TEP             | Tetraethyl pyrophosphate                 | Agriculture    |
| TFA             | Tetrahydrofurfuryl alcohol               |                |
| TNA             | Trinitroaniline                          |                |
| TNB             | Trinitrobenzene                          | Explosives     |
| TNG             | Trinitroglycerine                        | Explosives     |
| TNM             | Trinitromethane                          | Explosives     |
| TNT             | Trinitrotoluene                          |                |
| TNX             | Trinitroxylene                           | Explosives     |
| TOF             | Trioctyl phosphate                       | Explosives     |
| TPG             | Triphenyl guanidine                      | Plastics       |
| TSP             | Trisodium o-phosphate                    | Rubber         |
|                 | Tetrasodium phosphate                    |                |
| <b>V</b>        |  |                |
| VA              | Vinyl acetate                            |                |
| <b>Z</b>        |  |                |
| ZMA             | Zinc methylarsenate                      | Timber         |

# INDEX/GLOSSARY

## A

ABBREVIATIONS 8 (p141)

ABSOLUTE TEMPERATURE. At absolute zero temperature all movement of matter ceases. This temperature is theoretically unattainable.

Absolute zero: Celsius scale..... -273.15C  
Fahrenheit scale... -459.67F

ACCESS TO VALVE 6.1.3 (p92)

AFTERCOOLER 3.2.2 (p42)

AGITATOR table 3.7 (p45)

AIR IN STEAM 6.9.1 (p127) 6.10.1 (p128)

AIR LINE. Liquid removal 6.11.4 (p133)

ALLOYS. For pipe 2.1.4 (p4)

AMBIENT. Pertaining to the surroundings.

Usually refers to temperature

AMERICAN STANDARDS ASSOCIATION. 7.3 (p136)

ANCHOR 2.12.2 (p28) 6.2.8 (p101)

A pipe fixture used to hold piping rigidly at a chosen point. Position where piping is restrained is termed the 'anchor point'

ANGLE VALVE 3.1.5 (p35)

ANSI 7.3 (p136)

ARCHIVE. Place where drawings, specifications etc., may be permanently stored

ASA 7.3 (p136)

ATTRITION. See 'Change of Particle Size', 3.3.4 (p45)

AUTOClave. Vessel in which material or reactants are held under controlled conditions (time, temperature, pressure, etc.)

AUXILIARY PIPING 6.3.1 (p102)

## B

BACK WELD. In piping, a continuous weld made at the back of a butt-weld. Possible only if there is access to the interior

BACKCHECK 5.4.2 (p83)

BACKING RING = Chill ring chart 2.1 (p6)  
figure 2.1 (p6)

BALL FLOAT VALVE 3.1.9 (p38)

BALL VALVE. Check valve 3.1.7 (p37)

BALL VALVE. Rotary 3.1.6 (p36)

BAR. Traditional metric unit of pressure approximately equal to 1 atmosphere. See 'METRIC' - introduction, Part II. table M-7

BAROMETRIC LEG. If a process which takes place below atmospheric pressure requires water or other liquid to be continuously drained from it, this may be achieved by connecting the drain to a vertical pipe termed a 'barometric leg', the lower end of which is inserted in a seal pot. When the leg and seal are primed with liquid, draining from a low-pressure process can occur continuously. If the pressure of the process approaches zero (absolute), the leg must be at least 34 ft in height

BARSTOCK PLUG 2.5.4, figure 2.55 (p19)

BARSTOCK VALVE 3.1.11 (p39) Valve machined from solid metal

BATTERY LIMIT. Arbitrary line shown on drawings to define on-plot and off-plot areas. Also used to define limits of contractual responsibility within an on-plot area

BENCHMARK 5.3.1, figure 5.12 (p77)

BENDS, BUTT-WELDING 2.3.1 (p6)

BENT 6.1.2 (p90)

BEVEL The ends of pipe and butt-welding fittings are beveled (see chart 2.1) (p6) to aid making welded joints

BIBB 3.1.11 (p39)

BILL OF MATERIAL 5.6.1 (p86)

BLEED RING 2.7.1, figure 2.60 (p22)  
chart 5.7 (p60)

BLEED VALVE 3.1.11 (p39) figure 2.60 (p22)

BLENDER 3.3.2, table 3.7 (p45)

BLIND FLANGE 2.7.1 (p21) 2.7.2, figure 2.61 (p22)  
Flange without central opening, used for closure of flanged terminations. Rated similarly to other types of flanges - see 'Flange Data', Part II

BLOCK VALVE 3.1.11 (p39)

BLOWDOWN VALVE 3.1.11 (p39)

BLOWDOWN SYSTEM A (discharge) piping arrangement for removing material from a process, vessel, boiler, etc.

BLOWER 3.2.2 (p42)

BLOWOFF SYSTEM. Piping hookup used for blowing scale and foreign matter from tanks, boilers, etc.

BLOWOFF VALVE 3.1.9 (p38)

BOILER FEEDWATER 6.10.2 (p128)

BONNET 3.1.2 (p29)

BOTTOMS. See 'Column Operation' 6.5.2 (p114)

BREECHLOCK. See 'Bonnet' 3.1.2 (p31)

BREAKING LINES. figure 5.10 (p75)

BREATHING VALVE 3.1.11 (p39)

BRITISH STANDARDS INSTITUTION 7.3 (p136)

BRUNING 4.4.11 (p52)

BUILDING LAYOUT 6.15.3 (p135)

BUILDINGS. In relation to piping 6.15 (p135)  
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BULLHEAD TEE 2.3.2 (p9)

BUND. See 'DIKE'

BURIED PIPE. Dimensioning table 5.2 (p78)

BURSTING DISC = Rupture disc 3.1.9 (p38)

BUSHING, HEXAGON. Threaded 2.5.1,  
figure 2.42 (p16)

BUTT-WELDED PIPE JOINTS 2.3 (p6)

BUTTERFLY VALVE 3.1.6 (p37)

BYPASS. Valved length of piping that allows full or partial flow, arranged around a valve, valve assembly, equipment, etc. See figures 6.6 thru 6.11 (p96) for examples

BYPASS VALVE 3.1.11 (p39)

# C

## CAP

Butt-welding 2.3.3, figure 2.20 (p11)

Threaded 2.5.4, figure 2.54 (p19)

Socket-welding 2.4.4, figure 2.36 (p14)

**CARBON STEELS** are iron-based alloys having properties chiefly determined by their carbon content

**CATCHBASIN.** Receptacle designed to separate matter from a waste stream

**CATCHMENT.** Reservoir or basin

**CATHODIC PROTECTION.** Buried pipe can be protected from corrosion by wiring buried sacrificial anodes (usually cylinders of zinc) to the pipe. Galvanic corrosion then tends to occur in the zinc instead of the steel. Protection may also be provided by means of electric voltages and ground currents

**CAVITATION** 6.3.1 (p103)

**CELSIUS** = Centigrade. At atmospheric pressure (at sea level), on the Celsius scale, zero is the temperature at which ice forms; water boils at 100. tables M-6 & M-7 (Part II)

**CENTRIFUGE** 3.3.3, table 3.8 (p45)

**CERTIFIED DRAWING/PRINT.** Final vendor's print of equipment showing dimensions which will be maintained during manufacture

**CHATTERING** 3.1.4 (p35)

**CHECK VALVE** 3.1.7 (p37)

**CHECKER** 4.1.2 (p47) 5.4.1 (p83)

**CHILL RING** = Backing ring chart 2.1 (p6) fig 2.1 (p6)

**CIVIL PIPING** 1.1 (p1)

**CLEANOUT.** Arrangement for cleaning out a line or vessel

**CLEARANCE** 6.1.1, table 6.1 (p88) chart P-2 (Part II)

**CLOSING DOWN LINES** 6.1.3 (p93)

**CLOSURES.** Permanent figure 2.20 (p11)

Butt-welding 2.3.3 (p11)

Threaded 2.5.4 (p19)

Socket-welding 2.4.4 (p14)

**CLOSURES** Temporary 2.7 (p21) table 2.6 (p22)

**COAST & GEODETIC SURVEY** 5.3.1 (p77)

**COATINGS.** For pipe 2.1.4 (p5)

**COCK.** Simple plug valve in the smaller sizes

**CODES** 7.5 (p137)

ANSI B31. Code for pressure piping 7.5.1 (p137)

ASME Boiler and pressure vessel code 7.5.4 (p137)

**COLD SPRING** 6.1.1, figure 6.2 (p89)

**COLOR CODING**

Model 4.4.12 (p52)

Piping ANSI A13.1 (Part II)

**COLUMN, Fractionation/Distillation** 6.5.2 (p111) table 3.8 (p45)

**COLUMN PIPING** 6.5.2 (p111)

**COMMERCIAL PIPING** 1.1 (p1)

**COMPANION FLANGE.** A flange, or a flanging arrangement, custom-fabricated to mate with a non-standard flange on a item of equipment

**COMPOSITION DISC** 3.1.5 (p36) Non-metallic disc

**CONTAINMENT.** See DIKE

used in some globe valves

**COMPRESSOR** 3.2.2 (p42)

Piping 6.3.2 (p107)

**COMPRESSED AIR LINES.** Draining of 6.11.4 (p133)

**CONDENSATE** 6.9.1 (p127) 6.10.2 (p128)

**CONNECTOR**

Pipe-to-tube 2.5.1, figure 2.41 (p16)

Quick connector 2.8.1 (p22)

**CONSOLE.** An arrangement of gages and controls mounted in a desk or cabinet, from which a process may be monitored and controlled

**CONSTANT LOAD HANGER** 2.12.2 (p28)

**CONTINUATION SHEET.** See 'Process & Service Lines on Piping Drawings' 5.2.8 (p73) Any sheet on which information is continued

**CONTROL STATION** 6.1.4 (p95)

figures 6.6 thru 6.11 (p96)

Symbol chart 5.7 (p60)

**CONTROL VALVE** 3.1.10, figure 3.4 (p39)

**CONVEYED FLUID.** This term is used in the Guide for liquid or gas carried by piping

**COOLER.** Heat exchanger used to cool process fluid

**COOLING WATER.** Water used to cool process fluid or equipment

**COORDINATE** 5.3.1 (p77)

**COPYING PROCESSES** 4.4.11 (p52)

**CORROSION.** Conveyed fluid may attack materials from which pipe and fittings are made. The degree of corrosion will depend on the pipe material, the conveyed fluid, its temperature and concentration, time of exposure, possible presence of water or air, and whether galvanic action is also present

**CORROSION ALLOWANCE.** Additional thickness of metal in excess of that calculated for strength

**COUPLING**

Threaded FULL- 2.5.1 (p15) 2.5.3 (p18) figures 2.37 (p15) 2.49 (p18)

Threaded HALF- 2.5.3, figure 2.49 (p18)

Threaded REDUCER- 2.5.1 (p15) figure 2.38 (p16)

Socket-welding FULL- 2.4.1, figure 2.21 (p12)

Socket-welding HALF- 2.4.3, figure 2.31 (p14)

Socket-welding REDUCER 2.4.1, figure 2.22 (p12)

**CRASH PANEL.** Breakable panel thru which personnel may escape from a hazard in a building

**CROSS**

Butt-welding 2.3.2, figure 2.17 (p10)

Threaded 2.5.2 (p17) figure 2.48 (p18)

Socket-welding 2.4.2, figure 2.30 (p13)

**CRYOGENIC.** Refers to very low temperatures and equipment used at these temperatures. Term usually applies to -200F and colder

**CYCLONE** 3.3.3, table 3.8 (p45)

# D

- DAMPENER.**  
For compressor 3.2.2 (p42)  
Hydraulic 2.12.2 (p28)
- DASHPOT.** Piston-type device used for damping mechanical movement
- DATUM** See 'Vertical Reference' 5.3.1 (p77)
- DAVIT** 6.5.2 (p115) figure 6.27 (p112)
- DAY TANK.** Term used for storage tank, holding limited supply of fuel, etc.
- DEAD WEIGHTING.** Method of measuring pressure of fluid in a line. Device having a platform on which weights can be placed, temporarily fitted to vertical valved branch; weights balance line pressure. Used for calibration
- DEADMAN.** Anchor permanently set into ground for erection purposes. Used for securing cables
- DEAERATOR** 3.3.3, table 3.8 (p45)
- DEFLECTION OF PIPE** 6.2.6 (p100)  
See 'SPANS For Pipes', Part II
- DEFOAMER** 3.3.3, table 3.8 (p45)
- DEMINERALIZED WATER.** Water with all forms of hardness (dissolved minerals) removed
- DESICCANT.** A drying agent, such as concentrated sulfuric acid or silica gel
- DESICCATOR.** Equipment for removing water or other liquid from a process material by applying vacuum, heat, or by chemical means
- DESUPERHEATER.** Device for reducing superheat in steam, usually by adding water to the steam
- DETAIL.** See 'Elevations (Sections) & Details' 5.2.8 (p73)
- DEWPOINT.** Temperature at which a vapor forms liquid ('dew') on cooling
- DIAPHRAGM VALVE** 3.1.11 (p39)
- DIAZO** 4.4.11 (p52)
- DIKE.** Shaped wall or embankment surrounding one or more storage tanks to form a basin able to hold the contents of tank(s), in the event of rupture. In the US, usually 100% of the largest tank or 10% of the total, whichever is greater
- DIMENSIONING** 5.3 (p76) figure 5.13 (p78)  
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figure 5.12, table 5.2 (p78)
- Fitting makeup 5.3.3 (p80)
- Gasket. See 'Dimensioning to Joints', 5.3.3 (p79)
- Iso 5.3.4, figure 5.15 (p81)
- Offsets for iso figure 5.16 (p82)
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- Spool 5.3.5, figure 5.17 (p82)
- To joint 5.3.3 (p79)
- To nozzle 5.3.3 (p79) table 5.2 (p78)
- To pump. See 'Plot plan' 5.2.7 (p72) figure 6.17 (p104)
- To valve 5.3.3 (p80)
- Vessel figure 5.14 (p80)
- DIRECTION OF FLOW LINE.** See 'Flow Lines', 5.2.3 (p67)
- DISCHARGE VALVES** 3.1.9 (p38)
- DISHED HEAD** 2.3.3 (p11)  
Volume chart T-2 (Part II)
- DISTILLATION COLUMN** 3.3.3, table 3.8 (p45)  
Piping 6.5.2 (p115)
- DIVERTING VALVE** 3.1.8 (p38)
- DOUBLE-BLOCK-AND-BLEED** 2.7.1, fig. 2.60 (p22)  
See 'Make Maintenance Safe' 6.1.3 (p93)
- DOUBLE EXTRA STRONG.** 2.1.3 (p3)  
Manufacturers' weight designation for wall thickness of pipe and fittings
- DOWNCOMER.** A line which conveys fluid downward
- DOWTHERM.** 6.9.2 (p127) See 'Jacketing' 6.8.2 (p122)
- DRAFTING**  
Control stations 6.1.4 (p95) chart 5.7 (p60)  
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- DRAFTING MACHINES** 4.4.8 (p51)
- DRAFTSMAN** 4.1.2 (p47)
- DRAIN**  
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On P&ID 5.2.4 (p69)  
On pump 6.3.1 (p102)  
Symbol chart 5.7 (p60) chart 5.28 (p56)
- DRAIN HUB** Funnel fitted in floor and connected to a drain line
- DRAIN VALVE** 3.1.11 (p39)
- DRAINAGE** (1) System of drains (2) Act or process of draining
- DRAINING**  
Air line 6.11.4 (p133)  
Steam line 6.10.4 (p128) 6.10.9 (p129)
- DRAWING NUMBER** 4.2.4 (p49)
- DRAWING PAPER** 4.4.1 (p50)  
Sizes. See 'Paper' 4.4.1 (p50) chart S-6M (Part II)
- DRAWING REGISTER.** See 'Drawing Control', 4.2.4 (p49)
- DRAWING SHEETS.** See 'DRAWING PAPER' (p50) & (Part II)
- DRAWINGS**  
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- DRESSER COUPLING** 2.8.2 (p23)
- DRIP VALVE** A drain valve used on driplegs 3.1.11 (p39)  
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- DRIPLEG** 2.10.5, figure 2.70 (p25)  
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- DRY STEAM** 6.9.1. chart 6.3 (p127)
- DRYER** 3.3.3 (p45) 6.10.3 (p128) table 3.8 (p45)
- DRYSEAL** 2.5.5 (p19)
- DUMMY LEG** 2.12.2 (p28)  
figure 2.72A (p26) table 6.3 (p101)
- DYELINE** 4.4.11 (p52)

# E

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ELBOLET  
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ELEVATIONS  
Dimensions 5.3.2 (p77) table 5.2 (p78)  
Views. 5.2.6 (p70) See 'Elevations  
(Sections) & Details' 5.2.8 (p73)  
ELL. See ELBOW  
EJECTOR. A type of pump in which a partial  
vacuum is created by passing steam or other  
fluid under pressure thru a neck or venturi  
with a branch at the narrowest part. Suc-  
tion is created in the branch  
EQUIPMENT  
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EXPANSION JOINT 2.9.1 (p23)  
figures 2.63 thru 2.66 (p 23,24)  
EXTRA HEAVY. Traditional term used for Class  
250 cast-iron fittings  
EXTRA STRONG. Manufacturers' designation for  
wall thickness of pipe and fittings  
2.1.3 (p3)  
EXTRUDED NOZZLE. Hot-formed outlet made in  
pipe or vessel by pulling shaped dies thru  
a hole made in the wall

# F

FAN table 3.3 (p42)  
FAHRENHEIT. Scale of temperature formerly  
used in the English-speaking countries, now  
widely replaced by the international Celsius  
(or Centigrade) scale. At atmospheric press-  
ure (at sea level), on the Fahrenheit scale,  
32 is the temperature at which ice forms;  
water boils at 212. tables M-6 & M-7 (PartII)  
FIELD. (1) Construction site ('job site')  
where piping is erected. (2) Field engineer-  
ing office  
FIELD WELD. Weld made at the time of erection  
of piping at the site  
Symbol for. chart 5.3 (p57) figure 5.15 (p81)  
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Threaded 2.5, chart 2.3 (p15)  
Socket-welding 2.4, chart 2.2 (p11)  
FLAG. To identify, or to draw attention to,  
an item on a drawing by means of a symbol,  
note, panel or other mark  
FLAME ARRESTOR. A device to prevent a flame  
front from moving upstream in a line or  
vessel. For small lines, may consist of a  
wire screen. For larger lines, arrangements  
of multiple parallel plates or tubes are  
used. Principally used on vent lines from  
tanks. Symbol chart 5.7 (p60)  
FLAMMABLE LIQUID. Safety guidelines 6.14 (p134)  
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Welding-neck 2.3.1, figure 2.6 (p8) tables F “  
FLAP VALVE 3.1.11 (p40)  
FLARESTACK A stack located away from the  
processing area, to which relief headers may  
be run for burning waste hydrocarbons or  
other flammable vapors. 6.11.3 (p133)  
FLASH STEAM 6.9.1 (p127)  
FLASHING  
Steam 6.10.8 (p129)  
Building construction. A piece of metal or  
other material used to cover or protect  
certain joints from the weather, such as  
where a chimney joins a roof  
FLASHPOINT of flammable liquid. Temperature  
at which the amount of vapor given off is  
sufficient to form an ignitable mixture with  
air. Highly flammable liquids have low  
flashpoints  
FLAT FACE. Flange 2.6.1 (p20)  
FLEXIBILITY figure 6.1 (p89)  
FLEXIBLE PIPING 2.9.2 (p24)  
Expansion joint 2.9.1 (p23)  
FLOTATION TANK table 3.8 (p45)  
FLOOR STAND. See 'Stem' 3.1.2 (p31)  
FLOW DIAGRAM 5.2.3 (p65)  
FLOW LINE  
On flow diagram 5.2.3 (p65)  
On P&ID 5.2.4 (p68)  
FLUID. Any material capable of flowing. In  
the Guide, term is used to denote either a  
liquid or a gas. Powders may also be  
considered fluids

FLUSH-BOTTOM TANK VALVE 3.1.9 (p38)  
 FOOT VALVE 3.1.7 (p37)  
 FOREIGN MATTER. Any unwanted material that enters a system from outside  
 FOREIGN PRINT. Print of a drawing originating in another group, department or company  
 FOREIGN STANDARDS 7.3 (p137)  
 FRACTIONATION COLUMN 3.3.3. table 3.8 (p45)  
 Piping 6.5.2 (p111)  
 FROST LINE. The lowest depth in the ground which chills to 32F (0C)  
 FULL-COUPLING. See COUPLING

## G

GAGE. A device for measuring or registering level, pressure, temperature, etc.  
 GAGE GLASS. Glass used to show liquid level, usually in the form of a vertical glass tube with end connections  
 GALVANIZING. The coating of metal with zinc by electroplating or hot-dipping  
 GASKET 2.6.4, table 2.5 (p21)  
 Dimensioning. See 'Dimensioning to Joints', 5.3.3 (p79)  
 GATE VALVE 3.1.4 (p35)  
 GIRT. A horizontal member of a building to which the panels forming the sides of the building are fitted  
 GLAND. A sleeve within a stuffing box fitted over a shaft or valve stem and tightened against compressible packing so as to prevent leakage while allowing the shaft or stem to move  
 GLASS PIPE 2.1.4 (p5)  
 Supporting 6.2.7 (p100)  
 GLOBE VALVE 3.1.5 (p35)  
 GRADE. See 'Vertical Reference' 5.3.1 (p77)  
 GRADE BEAM. Beam which is used to support a floor at ground level  
 GROUND JOINT. Fine finish on two metal surfaces forming face-to-face leak-tight joint  
 GROUP LEADER 4.1.2 (p47)  
 GROUT. A thin layer of concrete poured on a set concrete foundation, between the foundation and the baseplate of the equipment which will rest on it. The baseplate is

firmly bolted down on the level surface of the grout after it has hardened  
 GUIDE 2.12.2 (p28) 6.2.8 (p101)  
 figure 2.72A (p26)  
 GUTLINE. See 'Tracing' 6.8.2 (p123)

## H

HALF-COUPLING  
 Threaded 2.5.3, figure 2.49 (p18)  
 Socket-welding 2.4.3, figure 2.31 (p14)  
 HANDRAIL. See RAILING  
 HANGER 2.12.2 (p28)  
 Constant-load hanger 2.12.2 (p28)  
 Spring hanger 2.12.2 (p28)  
 HARNESS PIPING 6.3.1 (p102)  
 HEAD. Pressure 3.2.1 (p41)  
 HEADER. A pipe serving as a principal supply or return line  
 HEADER VALVE 3.1.11 (p40)  
 HEAT EXCHANGER 3.3.5 (p45) figure 6.32 (p116)  
 chart H-1 (Part II)  
 Data sheet 6.6.1 (p116)  
 Piping to 6.6 (p116)  
 HEXAGON BUSHING 2.5.1, figure 2.42 (p16)  
 HIGH POINT FINISHED GRADE. See 'Vertical Reference' 5.3.1 (p77)  
 HOLDING TANK. Tank in which liquid (or gas) is held pending further processing or treatment  
 HOMOGENIZER 3.3.4 (p45)  
 HOSE CONNECTOR 2.8.1 (p22)  
 HOSE VALVE 3.1.11 (p40)  
 HOT TAP. A technique for branching into a line under pressure without having to close the line down  
 HOTWELL. A sump, tank, or other receptacle for holding discharges of hot liquids.  
 6.10.4 (p128)  
 HYDRAULIC ACCUMULATOR. Stores liquid under pressure. Typically a device consisting of a cylinder and piston which is actuated by a weight, spring, or compressed gas. On the opposite side of the piston, the driven fluid, such as water or oil, is stored  
 HYDRAULIC DAMPENERS 2.12.2 (p28)  
 Symbol chart 5.2B (p56)

HYDRAULIC RESISTANCE of pipe and fittings 6.1.1 (p90) table F-10 (Part II)  
 HYDROSTATIC TESTING 6.11.2 (p132)  
 HYGIENIC CONSTRUCTION. Pipe, valves, pumps and other equipment used to handle food-stuffs and drugs should be hygienically constructed; which means that all surfaces contacting the material must be smooth, non-toxic and corrosion proof. Plastics and rubbers should not incorporate (as fillers) substances that may contaminate. Materials free from such contaminants may be referred to as 'white' rubber, etc.

## I

INCONEL. A high-nickel alloy containing chromium and iron. Resistant to oxidation and corrosion  
 INCREASER = Swage or reducer  
 INSTRUMENT AIR. See 'Compressed Air Usage' 6.3.2 (p109)  
 INSTRUMENT CONNECTION 6.7 (p119) chart 6.2 (p118)  
 INSTRUMENT LOOP 5.5.3 (p84)  
 INSTRUMENT SOCIETY OF AMERICA 5.5.1 (p84) table 7.3 (p138)  
 INSTRUMENTATION 5.5 (p84)  
 Coding table 5.3 (p85)  
 Function 5.5.2 (p84)  
 Mounting 5.5.4 (p85)  
 On flow diagram 5.2.3 (p65)  
 On P&ID 5.2.4 (p68)  
 Signal lead 5.5.6 (p85) chart 5.1 (p54)  
 INSULATION. Thermal  
 On P&ID 5.2.4 (p68)  
 Personnel protection 6.8.1 (p122)  
 Thickness 6.8.1, tables 6.7 & 6.8 (p122)  
 INTERCOOLER 3.2.2 (p42)  
 INTERCONNECTING P&ID 5.2.4 (p68)  
 INTERFACE. Boundary common to two systems. See figure 6.3 points (10) & (14) (p91)  
 INVERT ELEVATION ('IE') is the elevation of the bottom of the internal surface of a buried pipe table 5.2 (p78)

INVENTORY. A listing of pipe and other items of hardware maintained in stock

IRON PIPE 2.1.4 (p4)

IRON PIPE SIZE 2.1.3 (p3)

ISO. International Standards Organization

See 'METRIC' - introduction, Part II

ISO = Isometric 5.2.6 (p70) 5.2.9 (p75)

figure 5.15 (p81) figure 5.16 (p82)

Checking 5.4.4 (p83)

Numbering 5.2.9 (p76)

ISOLATING VALVE 3.1.11 (p40)

ISSUING DRAWINGS 5.4.3 (p83)

## J

JACK SCREW. Screw provided in orifice flanges and sometimes flanges for line blinds for the purpose of temporarily holding flanges apart in order to insert/remove orifice plate or line blind. Two screws are provided (one per flange) placed 180 degrees apart. figure 2.59 (p22)

JACKETING 6.8.2 (p122)

JOB FUNCTIONS 4.1.2 (p47)

JOB NUMBER. Company account number to which work is charged. Appears on all paperwork for a project

JOULE. The work done when the point of application of a force of 1 newton is displaced through a distance of 1 meter in the direction of the force

JUMPOVER table A-2 (Part II)

## K

kelvin. SI unit of temperature. Defined as "the fraction 1/273.16 of the thermodynamic temperature of the triple point of water." [The triple point of water is the solid, liquid, vapor phase, as ice begins to form on cooling.] Zero on the thermodynamic scale is 273.15 kelvins below zero on the Celsius scale. A kelvin is a temperature 'interval', or difference. kelvin is not expressed in degrees. One kelvin is equal to one 'degree'

Celsius. Thus twenty degrees on the Celsius scale is 293.15K. table M-7 (Part II)

KNIFE-EDGE VALVE 3.1.11 (p40)

KNOCK-OUT DRUM/POT. A stream of gas containing drops of liquid is passed thru a knock-out drum in order to slow down the flow and allow the liquid to separate and collect

## L

LAND on beveled end. chart 2.1 (p6)

LANTERN RING. See 'Bonnet' 3.1.2 (p32)

LAP-JOINT FLANGE 2.3.1, figure 2.10 (p9)

LATERAL

Butt-welding 2.3.2, figure 2.18 (p10)

Threaded 2.5.2 (p17) figure 2.47 (p18)

Socket-welding 2.4.2, figure 2.29 (p13)

LATROLET

Butt-welding 2.3.2, figure 2.15 (p10)

Threaded 2.5.3, figure 2.52 (p18)

Socket-welding 2.4.3, figure 2.34 (p14)

LEROY 4.4.6 (p51)

LETTERING 4.4.6 (p51)

LEVEL GAGE. 6.7.4 (p119)

LINE BLIND. 2.7.1 (p21) figure 2.59 (p22)

Symbol. chart 5.6 (p59)

LINE BLIND VALVE 2.7.1 (p21) 3.1.4 (p35)

LINE DESIGNATION SHEET 4.2.3 (p49) 5.2.5 (p70)

LINE NUMBER

P&ID 5.2.4 (p68)

Piping drawings. See 'Process & Service Lines on Piping Drawings' 5.2.8 (p73)

Iso 5.2.9 (p76)

Spool 5.2.9 (p76)

LININGS for pipe 2.1.4 (p5)

LIST OF EQUIPMENT 4.2.2 (p49)

LIST OF MATERIEL 5.6.1 (p86)

LOAD CELL. Weighing mechanism installed in the supports of tanks, etc.

LOW-PRESSURE HEATING MEDIA 6.9.2 (p127)

LUG. Projecting piece on a vessel, frame, etc., by which it may be held or lifted or used for an attachment

## M

MAIN. A principal section of pipe supplying service or process fluid. In a RING MAIN the fluid is continuously circulated around a closed loop of piping and may be drawn off at any point. Useful for hot/cold lines, or for slurries and other fluids with suspended solids that may separate

MAKEUP WATER. Water is lost in many processes and operations. Water inventory is restored by adding makeup water

MALLEABLE-IRON. A ductile cast iron produced by controlled annealing of white cast iron

MANHOLE table 6.1 (p88)

In column 6.5.2 (p114)

MANIFOLD. A chamber or pipe (header) having several branches

MANOMETER. See 'Orifice Plate Assembly' 6.7.5 (p120)

MANUFACTURERS' WEIGHT 2.1.3 (p3)

MATCHLINE. See 'Process & Service Lines on Piping Drawings' 5.2.8 (p73) figure 5.8 (p72)

MATERIAL BALANCE. A detailed tabulation of process material flowing into, thru and out of the process, showing the distribution of all significant components, including impurities

MATERIAL TAKEOFF. Estimated quantities for materials, taken from drawings

MILL Symbol chart 5.2A (p55)

MITER 2.3.1, figure 2.5 (p7)

MIXER 3.3.2, table 3.7 (p45)

MIXING 3.3.2 (p45)

MIXING VALVE 3.1.11 (p40)

MODEL of plant 4.4.12 (p52)

MONEL. Alloys consisting mainly of nickel and copper, which have good resistance to corrosion, abrasion and heat

MONUMENT 5.3.1 (p76) figure 5.12 (p77)

MULTIPOINT VALVE 3.1.8 (p38)

MYLAR FILM 4.4.1 (p50)

# N

NEEDLE VALVE 3.1.5 (p36)  
 NEWTON. Metric unit. The force to accelerate a mass of 1 kilogram at the rate of 1 meter per second, per second. SI unit (derived).  
 NIPOLET. Integral nipple/weldolet  
 Plain 2.4.3, figure 2.35 (p14)  
 Threaded 2.5.3, figure 2.53 (p19)  
 NIPPLE  
 Threaded 2.5.1, figure 2.39 (p16)  
 Shaped 2.3.2, figure 2.19 (p10)  
 NON-RETURN VALVE 3.1.7 (p37) 3.1.11 (p40)  
 NON-RISING STEM See 'Stem' 3.1.2 (p31)  
 Type of valve stem which rotates but does not rise when valve is operated  
 NORTH. 'Plant north' & 'true north'. See 'Horizontal Reference' 5.3.1 (p76) and 'Allocating Space on the Sheet' 5.2.8 (p73) figure 5.11 (p77)  
 NOZZLE. A protruding port of a vessel, tank, pump, etc. to which piping is connected.  
 Column 6.5.2 (p114)  
 Heat exchanger 6.6.2 (p117)  
 Pump. See 'Typical Piping for Centrifugal Pumps' 6.3.1 (p102)  
 Supporting pipe at 6.2.8 (p101)  
 Vessel 6.5.1 (p111)  
 NUB. Spacer (protrusion) on a backing ring or insert.  
 NUMBER OF LINE. See 'Flow Lines on P&ID's' 5.2.4 (p68)

# O

OBLIQUE DRAWING 5.2.6 (p70)  
 OFF-PLOT. Refers to area outside the on-plot area, or to area between on-plot areas. See BATTERY LIMIT  
 ON-PLOT. Refers to the area of a particular plant unit or complex. There can be more than one on-plot area in the same manufacturing site. See BATTERY LIMIT  
 ON-SITE = In the field. Operations carried out at the construction site are termed on-site operations  
 OPERATOR for valve 3.1.2 (p29)  
 OPERATING HEIGHTS FOR VALVES 6.1.3 (p92) table 6.2 (p92) chart P-2 (Part II)

ORIFICE PLATE ASSEMBLY 6.7.5, figure 6.36 (p120)  
 Clearance around figure 6.38 (p121)  
 ORIFICE PIPE RUN table 6.6 (p121)  
 ORIFICE TAP. See 'Piping to Flange Taps' 6.7.5 (p120)  
 ORTHOGRAPHIC DRAWING 5.2.6 (p70)  
 OUTSIDE SCREW. See 'Stem' 3.1.2 (p29)  
 OUTSIDE SCREW & YOKE (OS&Y) See 'Stem' 3.1.2 (p29)

# P

P&ID = Piping and instrumentation diagram 5.2.4 (p68)  
 PACKING. Compressible material held in the stuffing box of a seal  
 PACKLESS VALVE. See 'Seals' 3.1.2 (p32)  
 PANTOGRAPH 4.4.8 (p51)  
 PAPER. Used in drafting 4.4.1 (p50) chart S-6M (Part II)  
 PAPER STOCK VALVE 3.1.11 (p40)  
 PARTS LIST 5.6.1 (p86)  
 PASCAL. Metric (SI) unit of pressure. The pascal is the pressure produced by a force of 1 newton over an area of 1 square meter  
 PENCIL. For drafting 4.4.2 (p50)  
 PENSTOCK. A channel leading water to a turbine or waterwheel  
 pH. A measure of the acid or alkaline strength of aqueous solutions. Neutral solutions have a pH of 7. Acids have a pH below 7. Alkaline/caustic liquids have a pH above 7  
 PHOTOGRAPHIC AIDS 4.4.13 (p52)  
 PICTORIAL VIEWS 5.2.6 (p70)  
 PIECEMARK = mark number. See 'Numbering Isos Spool Sheets, & Spools' 5.2.9 (p76)  
 PINCH VALVE 3.1.5 (p36)  
 PIPE  
 Areas. tables P-1 (Part II)  
 Bursting pressures. tables P-1 (Part II)  
 Data. tables P-1 (Part II)  
 Definition 2.1.1 (p3)  
 Deflection tables P-1 (Part II)  
 Diameters 2.1.3 (p3) tables P-1 (Part II)  
 Fittings 2.2.4 (p5) tables D (Part II)

Hanger 2.12 (p28)  
 How to specify 5.6.3 (p86)  
 Joints 2.2 (p5)  
 Lengths 2.1.2 (p3)  
 Linings 2.1.4 (p5)  
 Lugs welded onto 2.12.3 (p28)  
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 Maximum service pressure. tables P-1 (Part II)  
 Moment of inertia. tables P-1 (Part II)  
 Ordering 5.6.3 (p86)  
 Piperack 6.1.2 (p90) figure 6.3 (p91)  
 Pressure limits 2.1.5 (p5) tables P-1 (Part II)  
 Radius of gyration. tables P-1 (Part II)  
 Sag. tables P-1 (Part II)  
 Schedule number 2.1.3 (p3)  
 Section modulus. tables P-1 (Part II)  
 Sizes 2.1.2 (p3) tables P-1 (Part II)  
 Sleeve 5.2.8 (p74)  
 Spacing tables A (Part II)  
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 Steels table 2.1 (p4)  
 Stock lengths 2.1.2 (p3)  
 Support 2.12 (p28) 6.2 (p97)  
 Temperature limits 2.1.5 (p5)  
 Threads 2.5.5 (p19)  
 Wall thickness. 2.1.3 (p3) tables P-1 (Part II)  
 Weights. tables P-1 (Part II)  
 Welding to 2.12.3 (p28)  
 PIPE DOPE. Sealing compound used for making screwed connections. Teflon-based compounds are now usually specified unless teflon tape is used on the threads  
 PIPE SUPPORT 2.12 (p28) 6.2 (p97)  
 Calculations 6.2.4 (p97)  
 Design functions 6.2.1 (p97)  
 Expansion 6.2.5 (p100)  
 Loading 6.2.2 (p97)  
 Spring hanger and support 6.2.5 (p100)  
 PIPE-TO-TUBE CONNECTOR figure 2.41 (p16)  
 PIPERACK 6.1.2 (p90) figure 6.3 (p91)  
 PIPEWAY 6.1.2 (p90) tables A-1 (Part II)  
 PIPING  
 Butt-welded 2.3, chart 2.1 (p6)  
 Screwed 2.5, chart 2.3 (p15)  
 Socket-welded 2.4, chart 2.2 (p11)  
 PIPING & INSTRUMENTATION DIAGRAM 5.2.4 (p68)

PIPING DRAWINGS 5.2.7 (p71) 5.2.8 (p73)  
 Background 5.2.8 (p73)  
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 Line number. See 'Flow Lines on P&ID' 5.2.4 (p68) 5.2.8 (p73)  
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 PIPING FABRICATION DRAWING 5.2.9 (p75)  
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 PIPING USES 1.1 (p1)  
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 PLANIMETER 4.4.8 (p51)  
 PLANT. Building of 1.2, chart 1.1 (p1)  
 PLANT AIR See 'Compressed Air Usage' 6.3.2 (p109)  
 PLANT CONSTRUCTION chart 1.1 (p1)  
 PLANT NORTH. See 'Horizontal Reference', 5.3.1 (p76) figure 5.11 (p77)  
 PLASTIC PIPE 2.1.4 (p4)  
 Supporting 6.2.7 (p100)  
 PLENUM. Distribution component of a mechanical system of ventilation. Fresh air is forced into a box or chamber ('plenum') for distribution in a building  
 PLOT PLAN 5.2.7 (p72)  
 PLUG. Barstock figure 2.55 (p19)  
 PLUG GATE VALVE 3.1.4 (p35)  
 PLUG VALVE 3.1.4 (p35)  
 PLUMBING 1.1 (p1)  
 POCKETING In lines 6.2.6 (p100)  
 POLYMERIZATION. Generally, chemical reaction in which molecules combine to form larger molecules. Term mostly applied to reactions forming giant chain-like molecules, as in the production of plastics  
 'POP' SAFETY VALVE 3.1.9 (p38)

POTABLE WATER = Drinking water  
 PORT of valve. Refers to the seat aperture of a valve, but sometimes to the valve's ends  
 PRESSURE, ABSOLUTE and GAGE. Pressure expressed relative to absolute vacuum: pound per square inch absolute, abbreviated PSIA or psiA, is the unit normally used in the USA. Pressure above atmospheric is termed gage pressure, usually expressed as PSIG or psig. Normal atmospheric pressure is 14.7 PSIA. Adding 14.7 to the gage pressure gives the absolute pressure  
 PRESSURE REGULATOR 3.1.10 (p39)  
 PRESSURE SEAL. Valve. See 'Bonnet' 3.1.2 (p29)  
 PRESSURE VESSEL 6.5.1 (p111)  
 PRIMARY VALVE 3.1.11 (p39)  
 PRIME = Priming water, etc.  
 PROCESS EQUIPMENT. Equipment by which (or in which) is effected a physical or chemical change in process material 3.3 (p45)  
 PROCESS PIPING 1.1 (p1)  
 PROCESS WATER. Water that is added to the process stream  
 PROJECT GROUP chart 4.1 (p48)  
 PROPERTY LINE. Boundary of the site  
 PROPORTIONING PUMP 3.3.2, table 3.7 (p45)  
 PROPORTIONING VALVE 3.3.2, table 3.7 (p45)  
 PUMP 3.2.1 (p40)  
 Piping 6.3.1 (p102)  
 Selection chart 3.3 (p41)  
 PUMP PIPING 6.3.1 (p102)  
 PURGING. The flushing out of unwanted material from a system. Example: flooding piping with nitrogen to remove atmospheric oxygen  
 PURLIN. A longitudinal member fixed externally to the roof frame of a building to which the roofing panels are fitted  
 PYROMETER. A device used for measuring higher temperatures

## Q

QUICK-ACTING OPERATORS For valves 3.1.2 (p33)  
 QUICK CONNECTOR 2.8.1 (p22)  
 QUICK COUPLING 2.8.2 (p23)

## R

### RAILING

Dimensioning table 6.1 (p88) chart P-2 (Part II)  
 Symbol chart 5.8 (p61)  
 RAISED FACE (of flange) 2.6.1 (p20)  
 RANDOM LENGTH (of pipe) 2.1.2 (p3)  
 RANKINE. The Rankine scale measures temperature from absolute zero. One degree Rankine (R) = one degree Fahrenheit. table M-7 (Part II)  
 RAPIDOGRAPH Pen 4.4.6 (p51)  
 RATINGS OF FITTINGS table 2.2 (p5)  
 REACTION VESSEL 3.3.1 (p45)  
 REACTOR. Unit in which a controlled chemical reaction or process occurs  
 REBOILER. See 'Column Operation' 6.5.2 (p113)  
 RECEIVER 3.2.2 (p43)  
 REDUCER  
 Butt-welding 2.3.1 (p6) figure 2.3 (p7)  
 Threaded 2.5.1 (p15) figure 2.38 (p16)  
 Socket-welding 2.4.1, figure 2.22 (p12)  
 REDUCER INSERT 2.4.1, figure 2.23 (p12)  
 REDUCING ELBOW 2.3.1 (p6) figure 2.2 (p7)  
 REDUCING FLANGE 2.3.1, figure 2.8 (p8)  
 REDUCING TEE. How to order 2.3.2 (p9) table D-6 (Part II)  
 REGULATING VALVE 3.1.11 (p40)  
 REFERENCE DRAWING. Any drawing made by the design groups to which reference is made. The complete list of reference drawing numbers is best written on the main arrangement drawing  
 REFERENCE POINT 5.3.1, figure 5.11 (p77)  
 REFLUXING. See 'Column Operation' 6.5.2 (p111)  
 REINFORCEMENT 2.11 (p25)  
 Symbols chart 5.3 (p57)  
 REINFORCING RING. Shaped metal ring for reinforcing stub-ins, vessel nozzles, etc. Added metal compensates for metal removed from pipe or vessel wall  
 RELIEF HEADER 6.12.1 (p133) figure 6.3 point (7) (p91)  
 RELIEF VALVE 3.1.9 (p38) 6.1.3 (p92)  
 RELIEVING PRESSURE. Of liquids 6.12 (p133)  
 REMOVABLE SPOOL 2.7.1 (p21) figure 2.61 (p22)  
 RESISTANCE TO FLOW. In piping 6.1.1 (p90)  
 RETURN 2.3.1 (p6) figure 2.2 (p7)  
 REVAMP. To re-work or modify an existing

installation 4.4.13 (p52)  
 REVISION. Of drawings. See 'Issuing Drawings' 5.4.3 (p83)  
 RING-JOINT 2.6.1, figure 2.56 (p20)  
 Flange & gasket data. table M-7 (Part II)  
 RING MAIN. figure 6.22 (p107), 6.50 (p135)  
 RISER. A line which conveys fluid upward  
 ROLLED ELL/ROLLED TEE. See 'Plan View Piping Drawings' 5.2.8 (p74)  
 ROOT GAP 5.3.5 (p82) chart 2.1 (p6)  
 ROOT PENETRATION. Depth to which a groove (butt) weld extends into the 'root joint' (either side of root gap)  
 ROOT VALVE 3.1.11 (p40)  
 ROTAMETER 6.7.5, figure 6.35 (p120)  
 ROTARY BALL VALVE 3.1.6 (p36)  
 ROUNDHEAD PLUG. figure 2.55 (p19)  
 RUNUNDER. table A-3 (Part II)  
 RUPTURE DISC 3.1.9 (p38)

## S

SADDLE. (1) Shaped metal piece used for reinforcement. 2.11, figure 2.71 (p25) chart 5.3 (p57)  
 (2) Shaped metal piece attached to insulated pipe as a bearing surface for supporting. 2.12.2 (p28) 6.2.8 (p101) figures 2.72A (p26) 2.72B (p27)  
 SAFETY  
 Guidelines for flammable liquids. 6.14 (p134)  
 Valve placement 6.1.3 (p92) chart P-2 (Part II)  
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 SAFETY VALVE 3.1.9 (p38) 6.1.3 (p92)  
 SAGGING OF PIPE 6.2.6 (p100) tables P-1 (Part II)  
 SAMPLE POINT. It is often necessary to take a sample of material from a product line. Usually a small branch line with sampling valve is all that is required. However, if a high-pressure line has to be sampled it is best to run the sample line to a small vessel  
 SAMPLE POT. To sample a high-pressure line, it is necessary to provide a sample pot (a small drum or vessel) with a valved or unvalved vent to atmosphere. If a hot line is

being sampled, it may be necessary to provide the pot with a water-cooled coil  
 SAMPLING VALVE 3.1.9 (p38) 3.1.11 (p39)  
 SANITARY CONSTRUCTION. See HYGIENIC CONSTRUCTION  
 SATURATED STEAM 6.9.1 (p127)  
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 SCREWED PIPING. Describes an assembly of threaded components and pipe 2.5 (p15)  
 SCRUBBER 3.3.3, table 3.8 (p45)  
 SEAL WATER. Water used for pressurizing seals of a pump or other rotating equipment  
 SEAL WELD. Term used for circumferential fillet weld. chart 2.3 (p15)  
 SEAMLESS. Pipe formed by rolling and piercing a solid billet is termed 'seamless'. Describes pipe or fitting made without longitudinal weld  
 SEARCHING. Term usually refers to penetrating ability of a 'thin' (low viscosity) liquid  
 SECTION. See 'Elevations (Sections) & Details' 5.2.8 (p74) chart 5.8 (p61)  
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 SEPARATION 3.3.3 (p45)  
 SERVICE PIPING 1.1 (p1)  
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 SET PRESSURE. Pressure at which a pressure controller or valve is set to operate  
 SETTLEMENT STRAIN 6.1.1, figure 6.1 (p89)  
 SETTLING TANK. Tank in which process stream or effluent can be held to allow solids to separate. 3.3.3, table 3.8 (p45)  
 SEWAGE. Wastes from plant operations, buildings, etc. Sometimes includes ground or surface water  
 SEWERAGE. The collection and/or disposal of sewage  
 SHOE. For pipe 2.12.2 (p28) 6.2.8 (p101) figure 2.72A (p26)  
 SHUTOFF VALVE 3.1.11 (p40)  
 SI. See 'METRIC'- introduction, Part II  
 SIGHT GLASS. Window in a line or vessel

SITE. Area of plant construction  
 SITE PLAN 5.2.7 (p71)  
 SKELP. Metal in strip form that is fed into rolls to form pipe  
 SLIP-ON FLANGE 2.3.1, figure 2.7 (p8)  
 SLEEVE. For pipe. Short length of pipe, or proprietary fitting installed in wall or floor penetration thru which piping is run  
 SLOPING LINES 6.2.6 (p100) 6.10.4 (p128)  
 SLURRY VALVE 3.1.11 (p39)  
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 SOCKET-WELDING FLANGE 2.4.1, figure 2.27 (p13)  
 SOCKOLET 2.4.3. figure 2.32 (p14)  
 SOUR WATER. Water that has an acid content. Term may refer to an acidic effluent  
 SPARGER. A steam pipe with holes in it to disperse steam in water. figure 6.45 (p131)  
 SPATTER. The metal particles thrown off during arc or gas welding  
 SPECIFICATION.  
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 STOP VALVE 3.1.11(p40)  
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 STRAIN. Reaction, such as elongation or  
   compression, to stress. See STRESS  
 STRAINER 2.10.3, figure 2.68(p24)  
 STREET ELL table D-11(PartII)  
 STRESS. Force applied to material. Common  
   stresses on pipe are due to pressure of  
   contained fluid, and loading (self or  
   applied) causing bending of pipe

STRESS RELIEVE. Removal of internal strain in  
   metal items by heating and controlled cooling  
 STRESSES ON PIPING 6.1.1(p89)  
 STRIPPER 3.3.3, table 3.8(p45)  
 STRONGBACK. Pipe spool connected externally  
   to vessel, on which instruments are mounted.  
   figure 6.34(c)(p119)  
 STRUT. Any of various structural-steel memb-  
   ers (such as used in trusses), primarily  
   intended to resist longitudinal compression  
 STUB. Short length of pipe sometimes with  
   shaped end  
 STUB-IN 2.3.2, figure 2.11(p9) chart 5.3(p57)  
 STUDBOLT 2.6.3(p20) tables F(PartII)  
 STUFFING BOX. Recess in body or casing of a  
   valve, pump, expansion joint, etc. contain-  
   ing packing material under pressure so as to  
   form a seal about a sliding or rotating part  
 SUBHEADER. A header which is a branch from a  
   larger header  
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   Process. chart 5.2(p55,56AB)  
   Threaded piping. chart 5.4(p58)  
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   Utility station. 6.1.5(p95)  
   Valve chart 5.6(p59)

Valve operator chart 5.6(p59)  
 Welding 5.1.8, chart 5.9(p62)

## T

TACK WELD. Small, separated welds made to  
   position parts before welding fully  
 TAG. An identifying number or code applied to  
   an item  
 TANK NIPPLE 2.5.1, figure 2.39(d)(p16)  
 TANK CAR. Railroad car for transporting  
   liquids or gases  
 TANKER. Road vehicle for transporting liquids  
   or gases  
 TECHNOS PEN 4.4.6(p51)  
 TEE  
   Butt-welding 2.3.2, figure 2.12(p9)  
   Dimensions. tables D(PartII)  
   Reducing. table D-6(PartII)  
   Threaded 2.5.2, figure 2.46(p17)  
   Socket-welding 2.4.2, figure 2.28(p13)  
 TEMPLATES FOR DRAFTING 4.4.7(p51)  
 TEMPORARY STRAINER. See 'Screen', 2.10.4(p25)  
 THERMAL MOVEMENT. Changes in length (expans-  
   ion or contraction) occurring in piping with  
   variation of temperature  
 THERMAL STRESS 6.1.1(p89)  
 THERMINOL 6.9.2(p127) See 'Jacketing' 6.8.2(p122)  
 THERMON. See 'Getting Heat to the Process  
   Line' 6.8.2(p123)  
 THERMOWELL. A pocket, either screwed into a  
   line fitting (such as a coupling or thred-  
   olet) or welded into a pipe, to accommodate  
   a thermocouple or thermometer bulb 6.7.3(p119)  
 THREAD. For pipe and fittings 2.5.5(19)  
 THREDOLET 2.5.3, figure 2.50(p18)  
 THROAT TAP. A tapped pressure connection made  
   in the neck of a welding-neck flange as an  
   alternative to using an orifice flange  
 THROTTLING. Close regulation of flow thru a  
   valve in the just-open position  
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 TRAPPING STEAM LINES 6.10.11(p131)  
 TRIM. Critical internal surfaces of a valve body are sometimes made of special material such as stainless steel. These parts may include the disc and seat, stem, or other internal surfaces  
 TRIM PIPING 6.3.1(p102)  
 TRUSS. Structural frame based on the geometric rigidity of the triangle, composed of compression and tension members termed struts and ties  
 TUBE 2.1.1 (p3)  
 TURBINE PIPING 6.4 (p110)  
 TURNKEY PLANT. A plant constructed and made ready for client's immediate operation

## U

UNIFIED SCREW THREAD 2.6.3 (p21)  
 UNITRACE. See 'Tracing' 6.8.2 (p123)  
 UNION  
   Threaded 2.5.1, figure 2.40(p16)  
   Socket-welding 2.4.1, figure 2.24 (p12)  
 UNION BONNET. Valve construction allowing quick coupling and uncoupling of valve body and bonnet  
 UNION FITTING. A fitting with a union at one or more ends  
 UNLOADING 3.2.2 (p44)  
 US DEPARTMENT OF COMMERCE. Coast and Geodetic Survey 5.3.1 (p77)  
 USASI 7.3 (p136)  
 UTILITY PIPING 1.1 (p1)  
 UTILITY STATION 6.1.5, figure 6.12 (p95)  
   Symbol 6.1.5 (p95)

## V

VACUUM. The degree of vacuum can be quoted in PSIA, but more often either the pressure or the removed pressure is quoted as a 'head', usually the height of a column of mercury (Hg) in millimeters of mercury (mm Hg). Normal atmospheric pressure is 760 mm Hg  
 VACUUM BREAKER 3.1.11(p40)  
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   Operating height 6.1.3, table 6.2 (p92)  
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 VESSEL DRAWING 5.2.7 (p72) figure 5.14 (p80)  
 VESSEL PIPING 6.5.1 (p111)  
 VICTAULIC COUPLING. A 'quick-connect' method of joining pipe, fittings, valves, and equipment; manufactured by the Victaulic Company of America 2.8.2, figure 2.62 (p23)

## W

WATERHAMMER. A concussion due to:  
   (1) Pressure waves traveling in piping and meeting with obstructions. A valve closing too rapidly will create a pressure wave  
   (2) Condensate hurled against obstructions by high-velocity steam  
   See 6.10.2 (p128) 6.10.8 (p129)  
 WELD GAP 5.3.5 (p82) charts 2.1 (p6) & 2.2 (p11)  
 WELDING-NECK FLANGE. See 'Flanges' 2.3.1, figure 2.6 (p8) tables F (Part II)  
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 WELDING to pipe 2.12.3 (p28)  
 WELDOLET 2.3.2, figure 2.13 (p9)  
 WET STEAM 6.9.1, chart 6.3 (p127)  
 WINTERIZING. The provision of insulation, tracing, jacketing, or other means to prevent freezing of equipment and process or other fluids exposed to low temperatures.  
   Insulation 6.8.1 tables 6.7 & 6.8 (p122)  
   Jacketing 6.8.2 (p122) figure 6.39 (p123) chart 5.7 (p60)  
   Tracing 6.8.2 (p122) figure 6.40 (p125) chart 5.7 (p60)  
 WIRE DRAWING. Term describing the erosion of valve seats, usually due to the cutting action of foreign particles in high-velocity fluids occurring when flow is throttled  
 WORK POINT. An arbitrary reference from which dimensions are taken

## Y

YARD PIPING. Piping within the site and external to buildings  
 YOKE. See 'Stem' 3.1.2 (p29)

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- [123] JACKETED PIPE & HOSE - Parkes-Cramer Company

# THE 'PIPING GUIDE'

**FOR THE DESIGN AND DRAFTING  
OF INDUSTRIAL PIPING SYSTEMS**

**PART II**

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- 1) FOR INSULATION
- 2) IF THERMAL MOVEMENT WOULD REDUCE CLEARANCE

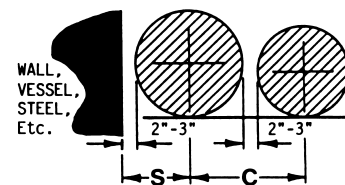
### D I M E N S I O N - 'C'

| LINES<br>WITHOUT<br>FLANGES                             | NOMINAL PIPE SIZE (NPS) |    |    |    |    |    |    |    |    |    |    |    |    |
|---|-------------------------|----|----|----|----|----|----|----|----|----|----|----|----|
|   | 2                       | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |    |
| N<br>O<br>M<br>I<br>N<br>A<br>L<br><br>P<br>I<br>P<br>E | 2                       | 5  | 6  | 6  | 7  | 8  | 10 | 11 | 11 | 12 | 13 | 14 | 16 |
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|   | 10                      | 10 | 10 | 11 | 12 | 13 | 14 | 15 | 15 | 16 | 17 | 18 | 20 |
|   | 12                      | 11 | 11 | 12 | 13 | 14 | 15 | 16 | 16 | 17 | 18 | 19 | 21 |
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|   | 20                      | 14 | 15 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 25 |
|   | 24                      | 16 | 17 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 27 |

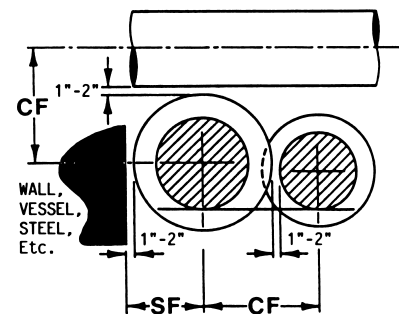
SURFACE-TO-CENTER  
OF PIPE DIMENSION

|   |    | 'S'                | 'SF'             |     |     |
|---|----|--------------------|------------------|-----|-----|
|   |    | WITHOUT<br>FLANGES | FLANGE<br>CLASS: |     |     |
|   |    |                    | 150              | 300 | 600 |
| N<br>O<br>M<br>I<br>N<br>A<br>L<br><br>P<br>I<br>P<br>E | 2  | 4                  | 4                | 5   | 5   |
|   | 3  | 4                  | 5                | 6   | 6   |
|   | 4  | 5                  | 6                | 6   | 7   |
|   | 6  | 6                  | 7                | 8   | 8   |
|   | 8  | 7                  | 8                | 9   | 10  |
|   | 10 | 8                  | 9                | 10  | 11  |
|   | 12 | 9                  | 11               | 12  | 12  |
|   | 14 | 9                  | 12               | 13  | 13  |
|   | 16 | 10                 | 13               | 14  | 15  |
|   | 18 | 11                 | 14               | 15  | 16  |
| S<br>I<br>Z<br>E  | 20 | 12                 | 15               | 17  | 17  |
|   | 24 | 14                 | 17               | 19  | 20  |

### PIPE WITHOUT FLANGES



### PIPE WITH FLANGES



### L I N E S   W I T H   F L A N G E S - D I M E N S I O N   'C F'

#### CLASS 150 & CLASS 150 FLANGES

|             | 150 | NOMINAL PIPE SIZE (NPS) OF FLANGED PIPE |    |    |    |    |    |    |    |    |    |    |    |  |
|-------------|-----|---|----|----|----|----|----|----|----|----|----|----|----|--|
| 150         |     | 2                                       | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |  |
| NPS         | 2   | 6                                       | 7  | 8  | 9  | 10 | 11 | 13 | 14 | 15 | 16 | 17 | 19 |  |
|             | 3   | 7                                       | 7  | 8  | 9  | 10 | 12 | 13 | 14 | 15 | 16 | 17 | 20 |  |
| O F         | 4   | 8                                       | 8  | 9  | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 20 |  |
|             | 6   | 9                                       | 9  | 10 | 11 | 12 | 13 | 15 | 16 | 17 | 18 | 19 | 21 |  |
| F L A N G E | 8   | 10                                      | 10 | 11 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 20 | 22 |  |
|             | 10  | 11                                      | 12 | 12 | 13 | 14 | 15 | 17 | 18 | 19 | 20 | 21 | 23 |  |
| D           | 12  | 13                                      | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 24 |  |
|             | 14  | 14                                      | 14 | 15 | 16 | 17 | 18 | 19 | 19 | 21 | 21 | 23 | 25 |  |
| P I P E     | 16  | 15                                      | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 26 |  |
|             | 18  | 16                                      | 16 | 17 | 18 | 19 | 20 | 21 | 21 | 23 | 23 | 25 | 27 |  |
|             | 20  | 17                                      | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 28 |  |
|             | 24  | 19                                      | 20 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 30 |  |

#### CLASS 300 & CLASS 300 FLANGES

|               | 300 | NOMINAL PIPE SIZE (NPS) OF FLANGED PIPE |    |    |    |    |    |    |    |    |    |    |    |
|---------------|-----|---|----|----|----|----|----|----|----|----|----|----|----|
| 300           |     | 2                                       | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
| NPS           | 2   | 6                                       | 7  | 8  | 9  | 11 | 12 | 13 | 15 | 16 | 17 | 18 | 21 |
|               | 3   | 7                                       | 8  | 9  | 10 | 11 | 12 | 14 | 15 | 16 | 18 | 19 | 22 |
| O F           | 4   | 8                                       | 9  | 9  | 10 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 22 |
|               | 6   | 9                                       | 10 | 10 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 21 | 23 |
| F L A N G E D | 8   | 11                                      | 11 | 12 | 13 | 14 | 15 | 17 | 18 | 19 | 20 | 22 | 24 |
|               | 10  | 12                                      | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 21 | 23 | 25 |
| P I P E       | 12  | 13                                      | 14 | 14 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 24 | 26 |
|               | 14  | 15                                      | 15 | 16 | 17 | 18 | 19 | 20 | 20 | 22 | 23 | 24 | 27 |
|               | 16  | 16                                      | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 28 |
|               | 18  | 17                                      | 18 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 29 |
|               | 20  | 18                                      | 19 | 19 | 21 | 22 | 23 | 24 | 24 | 25 | 26 | 27 | 30 |
|               | 24  | 21                                      | 22 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 32 |

### INSULATION

DIMENSIONS IN THESE TABLES ARE SPACINGS FOR BARE PIPE. FOR INSULATED LINES, ADD THE THICKNESS OF INSULATION AND COVERING TO THESE FIGURES

### CLASS 150 & CLASS 300 FLANGES

| 300 |    | NOMINAL PIPE SIZE (NPS) OF FLANGED PIPE |    |    |    |    |    |    |    |    |    |    |    |
|-----|----|---|----|----|----|----|----|----|----|----|----|----|----|
| 150 |    | 2                                       | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
| NPS | 2  | 6                                       | 7  | 8  | 9  | 11 | 12 | 13 | 15 | 16 | 17 | 18 | 21 |
|     | 3  | 7                                       | 8  | 9  | 10 | 11 | 12 | 14 | 15 | 16 | 18 | 19 | 22 |
| O   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| F   | 4  | 8                                       | 8  | 9  | 10 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 22 |
|     | 6  | 9                                       | 9  | 10 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 21 | 23 |
| F   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| L   | 8  | 10                                      | 10 | 11 | 13 | 14 | 15 | 17 | 18 | 19 | 20 | 22 | 24 |
|     | 10 | 11                                      | 12 | 12 | 14 | 15 | 16 | 18 | 19 | 20 | 21 | 23 | 25 |
| A   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| N   | 12 | 13                                      | 13 | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 22 | 24 | 26 |
|     | 14 | 14                                      | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 27 |
| G   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| E   | 16 | 15                                      | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 23 | 24 | 25 | 28 |
|     | 18 | 16                                      | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 24 | 25 | 26 | 29 |
| I   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| P   | 20 | 17                                      | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 25 | 26 | 27 | 30 |
|     | 24 | 19                                      | 20 | 20 | 21 | 22 | 23 | 24 | 25 | 27 | 28 | 29 | 32 |

### CLASS 300 & CLASS 600 FLANGES

| 600 |    | NOMINAL PIPE SIZE (NPS) OF FLANGED PIPE |    |    |    |    |    |    |    |    |    |    |    |
|-----|----|---|----|----|----|----|----|----|----|----|----|----|----|
| 300 |    | 2                                       | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
| NPS | 2  | 6                                       | 7  | 9  | 10 | 11 | 13 | 14 | 15 | 17 | 18 | 19 | 22 |
|     | 3  | 7                                       | 8  | 9  | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 20 | 22 |
| O   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| F   | 4  | 8                                       | 9  | 10 | 11 | 12 | 14 | 15 | 16 | 18 | 19 | 20 | 23 |
|     | 6  | 9                                       | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 24 |
| F   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| L   | 8  | 11                                      | 11 | 12 | 13 | 15 | 16 | 17 | 18 | 20 | 21 | 22 | 25 |
|     | 10 | 12                                      | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 21 | 22 | 23 | 26 |
| A   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| N   | 12 | 13                                      | 14 | 14 | 16 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 27 |
|     | 14 | 15                                      | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 24 | 25 | 27 |
| G   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| E   | 16 | 16                                      | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 25 | 26 | 28 |
|     | 18 | 17                                      | 18 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 26 | 27 | 29 |
| I   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| P   | 20 | 18                                      | 19 | 19 | 21 | 22 | 23 | 24 | 24 | 25 | 27 | 28 | 30 |
|     | 24 | 21                                      | 22 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 32 |

### CLASS 150 & CLASS 600 FLANGES

| 600 |    | NOMINAL PIPE SIZE (NPS) OF FLANGED PIPE |    |    |    |    |    |    |    |    |    |    |    |
|-----|----|---|----|----|----|----|----|----|----|----|----|----|----|
| 150 |    | 2                                       | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
| NPS | 2  | 6                                       | 7  | 9  | 10 | 11 | 13 | 14 | 15 | 17 | 18 | 19 | 22 |
|     | 3  | 7                                       | 8  | 9  | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 20 | 22 |
| O   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| F   | 4  | 8                                       | 8  | 10 | 11 | 12 | 14 | 15 | 16 | 18 | 19 | 20 | 23 |
|     | 6  | 9                                       | 9  | 11 | 12 | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 24 |
| F   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| L   | 8  | 10                                      | 10 | 12 | 13 | 15 | 16 | 17 | 18 | 20 | 21 | 22 | 25 |
|     | 10 | 11                                      | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 21 | 22 | 23 | 26 |
| A   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| N   | 12 | 13                                      | 13 | 14 | 15 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 27 |
|     | 14 | 14                                      | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 22 | 24 | 25 | 27 |
| G   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| E   | 16 | 15                                      | 15 | 16 | 17 | 18 | 20 | 21 | 22 | 23 | 25 | 26 | 28 |
|     | 18 | 16                                      | 16 | 17 | 18 | 19 | 21 | 22 | 23 | 24 | 26 | 27 | 29 |
| I   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| P   | 20 | 17                                      | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 25 | 27 | 28 | 30 |
|     | 24 | 19                                      | 20 | 20 | 21 | 22 | 24 | 25 | 26 | 27 | 29 | 30 | 32 |

### CLASS 600 & CLASS 600 FLANGES

| 600 |    | NOMINAL PIPE SIZE (NPS) OF FLANGED PIPE |    |    |    |    |    |    |    |    |    |    |    |
|-----|----|---|----|----|----|----|----|----|----|----|----|----|----|
| 600 |    | 2                                       | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
| NPS | 2  | 6                                       | 7  | 9  | 10 | 11 | 13 | 14 | 15 | 17 | 18 | 19 | 22 |
|     | 3  | 7                                       | 8  | 9  | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 20 | 22 |
| O   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| F   | 4  | 9                                       | 9  | 10 | 11 | 12 | 14 | 15 | 16 | 18 | 19 | 20 | 23 |
|     | 6  | 10                                      | 11 | 11 | 12 | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 24 |
| F   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| L   | 8  | 11                                      | 12 | 12 | 14 | 15 | 16 | 17 | 18 | 20 | 21 | 22 | 25 |
|     | 10 | 13                                      | 14 | 14 | 15 | 16 | 17 | 18 | 19 | 21 | 22 | 23 | 26 |
| A   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| N   | 12 | 14                                      | 15 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 27 |
|     | 14 | 15                                      | 16 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 24 | 25 | 27 |
| G   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| E   | 16 | 17                                      | 17 | 18 | 19 | 20 | 21 | 22 | 22 | 23 | 25 | 26 | 28 |
|     | 18 | 18                                      | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 29 |
| I   |    |   |    |    |    |    |    |    |    |    |    |    |    |
|     |    |   |    |    |    |    |    |    |    |    |    |    |    |
| P   | 20 | 19                                      | 20 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 30 |
|     | 24 | 22                                      | 22 | 23 | 24 | 25 | 26 | 27 | 27 | 28 | 29 | 30 | 32 |

### PIPEWAY WIDTH

When the order of lines, line sizes, flange classes (for lines with flanges), and insulation thicknesses for insulated lines have been decided, determine pipeway width from Tables A-1, A-2 and A-3, adding 25% so that the final design includes 20% (distributed) space for future piping. Additional space will usually be required for electrical and instrument trays/raceways.

For a **tentative** estimate of the pipeway width required for a selection of lines without flanges, of nominal sizes in the range NPS 2 thru NPS 8, either of the following factors may be used - the first is preferable:

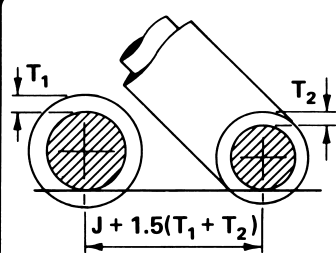
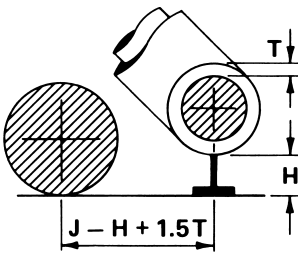
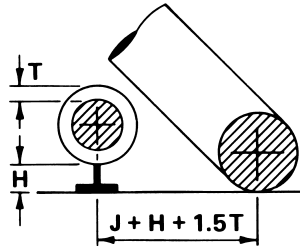
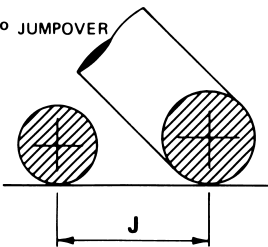
- (1) If all pipe sizes are known, add their nominal sizes in inches together and multiply by 0.34 to estimate the width in feet
- (2) If only the number of lines is known, multiply number of lines by 1.43 to estimate the width in feet

Either factor gives a pipeway width which includes insulation for 25% of lines, allows 20% of the width for the addition and re-sizing of lines, and allocates a further 20% of the width for future piping.

## 45° JUMPOVERS

**TABLE A-2**

45° JUMPOVER

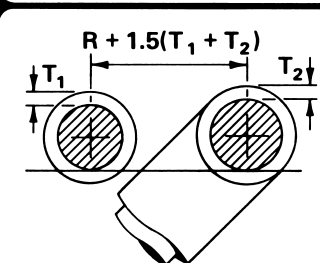
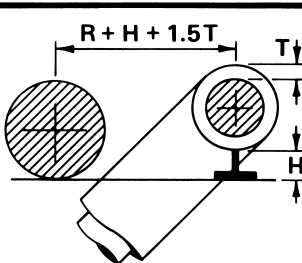
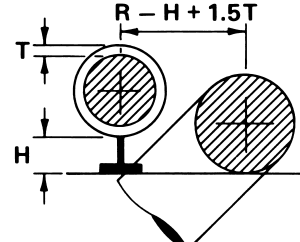
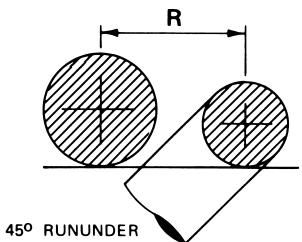


**BASIC SPACING 'J'**

| NPS  | JUMPOVER LINE |    |    |    |    |    |    |    |    |    |    |    |
|--|---------------|----|----|----|----|----|----|----|----|----|----|----|
|  | 2             | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
| A<br>D<br>J<br>A<br>C<br>E<br>N<br>T<br><br>L<br>I<br>N<br>E | 2             | 7  | 7  | 7  | 8  | 8  | 8  | 9  | 9  | 10 | 10 | 11 |
|  | 3             | 8  | 8  | 8  | 9  | 9  | 10 | 10 | 10 | 11 | 11 | 13 |
|  | 4             | 9  | 9  | 10 | 10 | 11 | 11 | 11 | 12 | 12 | 12 | 14 |
|  | 6             | 12 | 12 | 12 | 13 | 13 | 14 | 14 | 14 | 15 | 15 | 16 |
|  | 8             | 14 | 14 | 15 | 15 | 16 | 16 | 16 | 17 | 17 | 17 | 18 |
|  | 10            | 17 | 17 | 17 | 18 | 18 | 19 | 19 | 19 | 20 | 20 | 21 |
|  | 12            | 19 | 19 | 20 | 20 | 21 | 21 | 21 | 22 | 22 | 22 | 24 |
|  | 14            | 21 | 21 | 21 | 22 | 22 | 22 | 23 | 23 | 24 | 24 | 25 |
|  | 16            | 23 | 23 | 24 | 24 | 24 | 25 | 25 | 26 | 26 | 26 | 28 |
|  | 18            | 26 | 26 | 26 | 26 | 27 | 27 | 28 | 28 | 28 | 29 | 30 |
| 20   | 28            | 28 | 28 | 29 | 29 | 30 | 30 | 30 | 31 | 31 | 32 | 32 |
|  | 24            | 33 | 33 | 33 | 34 | 34 | 35 | 35 | 36 | 36 | 36 | 37 |

## 45° RUNUNDERS

**TABLE A-3**



**BASIC SPACING 'R'**

| NPS  | RUNUNDER LINE |    |    |    |    |    |    |    |    |    |    |    |
|--|---------------|----|----|----|----|----|----|----|----|----|----|----|
|  | 2             | 3  | 4  | 6  | 8  | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
| A<br>D<br>J<br>A<br>C<br>E<br>N<br>T<br><br>L<br>I<br>N<br>E | 2             | 7  | 8  | 9  | 12 | 14 | 17 | 19 | 21 | 23 | 26 | 33 |
|  | 3             | 7  | 8  | 9  | 12 | 14 | 17 | 19 | 21 | 23 | 26 | 33 |
|  | 4             | 7  | 8  | 10 | 12 | 15 | 17 | 20 | 21 | 24 | 26 | 33 |
|  | 6             | 8  | 9  | 10 | 13 | 15 | 18 | 20 | 22 | 24 | 26 | 34 |
|  | 8             | 8  | 9  | 11 | 13 | 16 | 18 | 21 | 22 | 24 | 27 | 34 |
|  | 10            | 8  | 10 | 11 | 14 | 16 | 19 | 21 | 22 | 25 | 27 | 35 |
|  | 12            | 9  | 10 | 11 | 14 | 16 | 19 | 21 | 23 | 25 | 28 | 35 |
|  | 14            | 9  | 10 | 12 | 14 | 17 | 19 | 22 | 23 | 26 | 28 | 35 |
|  | 16            | 10 | 11 | 12 | 15 | 17 | 20 | 22 | 24 | 26 | 28 | 36 |
|  | 18            | 10 | 11 | 12 | 15 | 17 | 20 | 22 | 24 | 26 | 29 | 36 |
| 20   | 10            | 12 | 13 | 15 | 18 | 20 | 23 | 24 | 27 | 29 | 32 | 36 |
|  | 24            | 11 | 13 | 14 | 16 | 19 | 21 | 24 | 25 | 28 | 30 | 37 |

### NOTES FOR TABLES A-2 & A-3

- (1) SPACING SHOWN IN THE DIAGRAMS ALLOWS A MINIMUM CLEARANCE OF 2-INCHES. COMPARE BASIC SPACING 'J' or 'R' WITH APPROPRIATE 'C' or 'CF' SPACING IN TABLE A-1 AND USE THE LARGER DIMENSION
- (2) 'H' IS THE EFFECTIVE SHOE HEIGHT AND 'T' IS THE THICKNESS OF INSULATION (WITH COVERING)
- (3) FOR SIMPLICITY, THE VALUE 1.5 HAS BEEN SUBSTITUTED FOR THE COEFFICIENT  $1/\sin 45$  (1.414....)

CLASS

600

## BUTT-WELDED PIPING DIMENSIONS

TABLE D-1

DIMENSIONS IN THIS TABLE INCLUDE 0.25-inch RAISED FACE ON FLANGES

## NOMINAL PIPE SIZE (NPS)

2

3

4

6

8

10

12

14

16

18

20

24

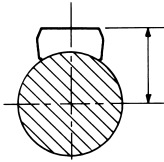
## FITTINGS

DIMENSIONS FROM ANSI B16.5, B16.9, B16.28 AND MANUFACTURERS DATA

## STRAIGHT TEE

TABLE D-6 FOR  
REDUCING TEES

## WELDOLET

STANDARD AND  
EXTRA-STRONG

BRANCH DIAMETER

2

3

4

## REDUCERS

CONCENTRIC  
& ECCENTRIC

## 90° LR ELLS

REGULAR &  
REDUCING

## 90° SR ELL

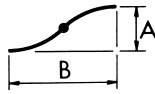


## 45° ELL (LR)



## OFFSET

(TWO 45° ELLS )

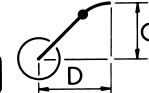


A

B

## ROLLED-ELL

(45° ELL + 90° LR ELL)



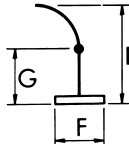
C

D

## 90° LR ELL

+ WELDING-NECK

## RAISED-FACE FLANGE



E

F

G

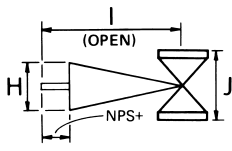
## VALVES

DIMENSIONS FROM ANSI B16.10 AND MANUFACTURERS DATA

## PLUG

VENTURI PATTERN: NPS 2-24  
REGULAR PATTERN: NPS 2-16

## GATE

DIMENSIONS ALSO  
APPLY TO GATE  
VALVES WITH BUTT-  
WELDING ENDS

H

I

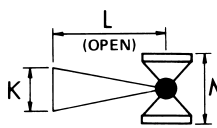
J

## BALL

LONG PATTERN:



## GLOBE

DIMENSIONS ALSO  
APPLY TO GLOBE  
VALVES WITH BUTT-  
WELDING ENDS

K

L

M

## CHECK

SWING CHECK: NPS 2-24  
TILTING DISC: NPS 2-24  
LIFT: NPS 2-12FLANGED  
& BUTT-  
WELDING

|                                |                              |                              |                              |                              |                              |                              |                              |                              |                              |                              |                              |
|--------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| 2.5                            | 3.38                         | 4.12                         | 5.62                         | 7                            | 8.5                          | 10                           | 11                           | 12                           | 13.5                         | 15                           | 17                           |
| 2.69                           | 3.25                         | 3.75                         | 4.81                         | 5.81                         | 6.88                         | 7.88                         | 8.5                          | 9.5                          | 10.5                         | 11.5                         | 13.5                         |
| -                              | 3.5                          | 4                            | 5.06                         | 6.06                         | 7.12                         | 8.12                         | 8.75                         | 9.75                         | 10.75                        | 11.75                        | 13.75                        |
| -                              | -                            | 4.25                         | 5.31                         | 6.31                         | 7.38                         | 8.38                         | 9                            | 10                           | 11                           | 12                           | 14                           |
| Swage-<br>Table<br>D-4         | 3.5                          | 4                            | 5.5                          | 6                            | 7                            | 8                            | 13                           | 14                           | 15                           | 20                           | 20                           |
| 3                              | 4.5                          | 6                            | 9                            | 12                           | 15                           | 18                           | 21                           | 24                           | 27                           | 30                           | 36                           |
| 2                              | 3                            | 4                            | 6                            | 8                            | 10                           | 12                           | 14                           | 16                           | 18                           | 20                           | 24                           |
| 1.38                           | 2                            | 2.5                          | 3.75                         | 5                            | 6.25                         | 7.5                          | 8.75                         | 10                           | 11.25                        | 12.5                         | 15                           |
| 1.94                           | 2.81                         | 3.56                         | 5.31                         | 7.06                         | 8.81                         | 10.62                        | 12.38                        | 14.12                        | 15.94                        | 17.69                        | 21.19                        |
| 4.69                           | 6.81                         | 8.56                         | 12.81                        | 17.06                        | 21.31                        | 25.62                        | 29.88                        | 34.12                        | 38.44                        | 42.69                        | 51.19                        |
| 3.12                           | 4.62                         | 6                            | 9                            | 12                           | 15                           | 18                           | 21.06                        | 24.06                        | 27.06                        | 30.06                        | 36.06                        |
| 4.50                           | 6.62                         | 8.5                          | 12.75                        | 17                           | 21.25                        | 25.5                         | 29.81                        | 34.06                        | 38.31                        | 42.56                        | 51.06                        |
| 6.12                           | 8                            | 10.25                        | 13.88                        | 17.5                         | 21.25                        | 24.38                        | 27.75                        | 31.25                        | 34.5                         | 37.75                        | 44.25                        |
| 6.5                            | 8.25                         | 10.75                        | 14                           | 16.5                         | 20                           | 22                           | 23.75                        | 27                           | 29.25                        | 32                           | 37                           |
| 3.12                           | 3.5                          | 4.25                         | 4.88                         | 5.5                          | 6.25                         | 6.38                         | 6.75                         | 7.25                         | 7.5                          | 7.75                         | 8.25                         |
| <sup>R</sup> 11.5 <sup>V</sup> | <sup>R</sup> 14 <sup>V</sup> | <sup>R</sup> 17 <sup>V</sup> | <sup>R</sup> 22 <sup>V</sup> | <sup>R</sup> 26 <sup>V</sup> | <sup>R</sup> 31 <sup>V</sup> | <sup>R</sup> 33 <sup>V</sup> | <sup>R</sup> 35 <sup>V</sup> | <sup>R</sup> 39 <sup>V</sup> | <sup>V</sup> 43 <sup>V</sup> | <sup>V</sup> 47 <sup>V</sup> | <sup>V</sup> 55 <sup>V</sup> |
| 9                              | 12                           | 16                           | 22                           | 24                           | 28                           | 30                           | 36                           | 38                           | 38                           | 42                           | 42                           |
| 21                             | 26                           | 33                           | 47                           | 53                           | 66                           | 73                           | 81                           | 93                           | 99                           | 107                          | 126                          |
| 11.5                           | 14                           | 17                           | 22                           | 26                           | 31                           | 33                           | 35                           | 39                           | 43                           | 47                           | 55                           |
| 11.5                           | 14                           | 17                           | 22                           | 26                           | 31                           | 33                           | 35                           | 39                           | 43                           | 47                           | 55                           |
| 12                             | 14                           | 18                           | 24                           | 36                           |                              |                              |                              |                              |                              |                              |                              |
| 21                             | 27                           | 33                           | 44                           | 47                           |                              |                              |                              |                              |                              |                              |                              |
| 11.5                           | 14                           | 17                           | 22                           | 26                           | 31                           | 33                           |                              |                              |                              |                              |                              |
| <sup>L</sup> 11.5 <sup>S</sup> | <sup>L</sup> 14 <sup>S</sup> | <sup>L</sup> 17 <sup>S</sup> | <sup>L</sup> 22 <sup>S</sup> | <sup>L</sup> 26 <sup>S</sup> | <sup>L</sup> 31 <sup>S</sup> | <sup>L</sup> 33 <sup>S</sup> | <sup>S</sup> 35 <sup>T</sup> | <sup>S</sup> 39 <sup>T</sup> | <sup>S</sup> 43 <sup>T</sup> | <sup>S</sup> 47 <sup>T</sup> | <sup>S</sup> 55 <sup>T</sup> |

- DIMENSIONS FOR COMBINATIONS OF FITTINGS AND INSTALLED WELDOLETS DO NOT INCLUDE THE 'WELD GAP' - REFER TO TEXT: SECTION 5.3.5
- DIMENSIONS IN THIS TABLE ARE NOMINAL AND FOR COMBINATIONS OF FITTINGS ARE ROUNDED TO 1/100-inch
- 'H', 'I', 'K' AND 'L' ARE THE LARGEST DIMENSIONS FOR MANUALLY-OPERATED CAST-STEEL VALVES FROM A SELECTION OF MANUFACTURERS
- GUIDELINES FOR THE USE OF GEAR AND POWERED OPERATORS WITH VALVES ARE GIVEN IN SECTION 3.1.2 OF THE TEXT


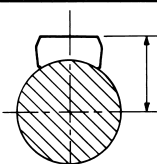
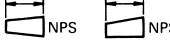
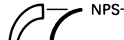


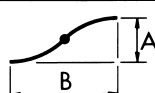
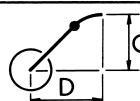
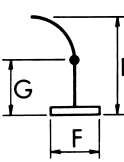

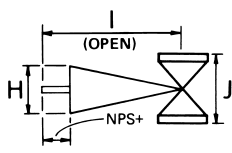

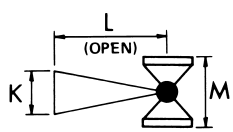

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|--------------------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|---------------|-------------|---------------|-------------|---------------|
| FRACTIONAL<br>EQUIVALENT | 0.06<br>1/16 | 0.12<br>1/8 | 0.19<br>3/16 | 0.25<br>1/4 | 0.31<br>5/16 | 0.38<br>3/8 | 0.44<br>7/16 | 0.50<br>1/2 | 0.56<br>9/16 | 0.62<br>5/8 | 0.69<br>11/16 | 0.75<br>3/4 | 0.81<br>13/16 | 0.88<br>7/8 | 0.94<br>15/16 |
|--------------------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|---------------|-------------|---------------|-------------|---------------|

# CLASS 300

# BUTT-WELDED PIPING DIMENSIONS

# TABLE D-2

DIMENSIONS IN THIS TABLE INCLUDE 0.06-inch RAISED FACE ON FLANGES

| NOMINAL PIPE SIZE (NPS)   |   |                 |             | 2                               | 3                                 | 4                              | 6   | 8   | 10  | 12  | 14  | 16  | 18  | 20                             | 24                             |                     |                   |                   |
|---|---|-----------------|-------------|---------------------------------|-----------------------------------|--------------------------------|---|---|---|---|---|---|---|--------------------------------|--------------------------------|---------------------|-------------------|-------------------|
| FITTINGS  | STRAIGHT TEE<br>TABLE D-6 FOR REDUCING TEES<br>  |                 |             |                                 |                                   |                                |   |   |   |   |   |   |   |                                |                                |                     |                   |                   |
|   | Weldolet<br><br>STANDARD AND<br>EXTRA-STRONG<br><br>   | BRANCH DIAMETER | 2           | 2.5                             | 3.38                              | 4.12                           | 5.62  | 7   | 8.5   | 10  | 11  | 12  | 13.5  | 15                             | 17                             |                     |                   |                   |
|   |   |                 | 3           | 2.69                            | 3.25                              | 3.75                           | 4.81  | 5.81  | 6.88  | 7.88  | 8.5   | 9.5   | 10.5  | 11.5                           | 13.5                           |                     |                   |                   |
|   |   |                 | 4           | -                               | 3.5                               | 4                              | 5.06  | 6.06  | 7.12  | 8.12  | 8.75  | 9.75  | 10.75   | 11.75                          | 13.75                          |                     |                   |                   |
|   | REDUCERS<br>CONCENTRIC & ECCENTRIC<br>   |                 |             | Swage-Table D-4                 | 3.5                               | 4                              | 5.5   | 6   | 7   | 8   | 13  | 14  | 15  | 20                             | 20                             |                     |                   |                   |
|   | 90° LR ELLS<br>REGULAR & REDUCING<br>  |                 |             | 3                               | 4.5                               | 6                              | 9   | 12  | 15  | 18  | 21  | 24  | 27  | 30                             | 36                             |                     |                   |                   |
|   | 90° SR ELL<br>   |                 |             | 2                               | 3                                 | 4                              | 6   | 8   | 10  | 12  | 14  | 16  | 18  | 20                             | 24                             |                     |                   |                   |
|   | 45° ELL (LR)<br>   |                 |             | 1.38                            | 2                                 | 2.5                            | 3.75  | 5   | 6.25  | 7.5   | 8.75  | 10  | 11.25   | 12.5                           | 15                             |                     |                   |                   |
|   | OFFSET<br>(TWO 45° ELLS)<br>   |                 |             | A<br>B                          | 1.94<br>4.69                      | 2.81<br>6.81                   | 3.56<br>8.56                                      | 5.31<br>12.81                                     | 7.06<br>17.06                                   | 8.81<br>21.31                                     | 10.62<br>25.62                                  | 12.38<br>29.88                                    | 14.12<br>34.12                                  | 15.94<br>38.44                 | 17.69<br>42.69                 | 21.19<br>51.19      |                   |                   |
|   | ROLLED- ELL<br>(45° ELL + 90° LR ELL)<br>  |                 |             | C<br>D                          | 3.12<br>4.50                      | 4.62<br>6.62                   | 6<br>8.5  | 9<br>12.75  | 12<br>17  | 15<br>21.25                                       | 18<br>25.5                                      | 21.06<br>29.81                                    | 24.06<br>34.06                                  | 27.06<br>38.31                 | 30.06<br>42.56                 | 36.06<br>51.06      |                   |                   |
| 90° LR ELL<br>+ WELDING-NECK<br>RAISED-FACE FLANGE<br> |   |                 | E<br>F<br>G | 5.75<br>6.5<br>2.75             | 7.62<br>8.25<br>3.12              | 9.38<br>10<br>3.38             | 12.88<br>12.5<br>3.88                             | 16.38<br>15<br>4.38                               | 19.62<br>17.5<br>4.62                           | 23.12<br>20.5<br>5.12                             | 26.62<br>23<br>5.62                             | 29.75<br>25.5<br>5.75                             | 33.25<br>28<br>6.25                             | 36.38<br>30.5<br>6.38          | 42.62<br>36<br>6.62            |                     |                   |                   |
| VALVES  | PLUG<br>VENTURI PATTERN: NPS 2-24<br>SHORT PATTERN: NPS 2-12<br>REGULAR PATTERN: NPS 14-24<br> |                 |             | S <sup>S</sup> 8.5 <sup>V</sup> | S <sup>S</sup> 11.12 <sup>V</sup> | S <sup>S</sup> 12 <sup>V</sup> | S <sup>S</sup> 15.88 <sup>V</sup>                 | S <sup>S</sup> 16.5 <sup>V</sup>                  | S <sup>S</sup> 18 <sup>V</sup>                  | S <sup>S</sup> 19.75 <sup>V</sup>                 | R <sup>R</sup> 30 <sup>V</sup>                  | R <sup>R</sup> 33 <sup>V</sup>                    | R <sup>R</sup> 36 <sup>V</sup>                  | R <sup>R</sup> 39 <sup>V</sup> | R <sup>R</sup> 45 <sup>V</sup> |                     |                   |                   |
|   | GATE<br><br>DIMENSIONS ALSO<br>APPLY TO GATE<br>VALVES WITH BUTT-<br>WELDING ENDS<br>          |                 |             | H<br>I<br>J                     | 8<br>21<br>8.5                    | 10<br>25<br>11.12              | 12<br>29<br>12                                    | 16<br>39<br>15.88                                 | 20<br>49<br>16.5                                | 24<br>59<br>18                                    | 24<br>67<br>19.75                               | 28<br>76<br>30                                    | 28<br>81<br>33                                  | 32<br>92<br>36                 | 36<br>102<br>39                | 36<br>123<br>45     |                   |                   |
|   | BALL<br>LONG PATTERN: NPS 2-24<br>SHORT PATTERN: NPS 2-6<br>                                   |                 |             | L <sup>L</sup> 8.5 <sup>S</sup> | L <sup>L</sup> 11.12 <sup>S</sup> | L <sup>L</sup> 12 <sup>S</sup> | L <sup>L</sup> 15.88 <sup>S</sup>                 | L <sup>L</sup> 19.75 <sup>S</sup>                 | L <sup>L</sup> 22.38 <sup>S</sup>               | L <sup>L</sup> 25.5 <sup>S</sup>                  | L <sup>L</sup> 30 <sup>S</sup>                  | L <sup>L</sup> 33 <sup>S</sup>                    | L <sup>L</sup> 36 <sup>S</sup>                  | L <sup>L</sup> 39 <sup>S</sup> | L <sup>L</sup> 45 <sup>S</sup> |                     |                   |                   |
|   | GLOBE<br><br>DIMENSIONS ALSO<br>APPLY TO GLOBE<br>VALVES WITH BUTT-<br>WELDING ENDS<br>        |                 |             | K<br>L<br>M                     | 10<br>20<br>10.5                  | 12<br>24<br>12.5               | 14<br>27<br>14                                    | 22<br>32<br>17.5                                  | 24<br>41<br>22                                  | 26<br>49<br>24.5                                  | 36<br>52<br>28                                  |   |   |                                |                                |                     |                   |                   |
|   | CHECK<br>SWING: NPS 2-24<br>TILTING DISC: NPS 2-12<br>LIFT: NPS 2-6, 10-12<br>                 |                 |             | FLANGED & BUTT-WELDING          |                                   |                                | S <sup>S</sup> T <sup>T</sup> L <sup>L</sup> 10.5 | S <sup>S</sup> T <sup>T</sup> L <sup>L</sup> 12.5 | S <sup>S</sup> T <sup>T</sup> L <sup>L</sup> 14 | S <sup>S</sup> T <sup>T</sup> L <sup>L</sup> 17.5 | S <sup>S</sup> T <sup>T</sup> L <sup>L</sup> 21 | S <sup>S</sup> T <sup>T</sup> L <sup>L</sup> 24.5 | S <sup>S</sup> T <sup>T</sup> L <sup>L</sup> 28 | S <sup>S</sup> 33              | S <sup>S</sup> 34              | S <sup>S</sup> 38.5 | S <sup>S</sup> 40 | S <sup>S</sup> 53 |

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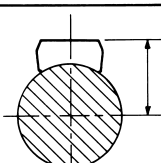
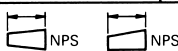
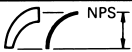

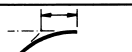
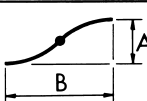
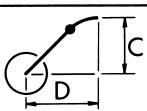
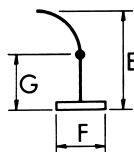

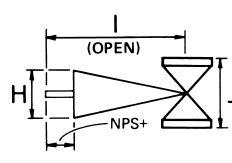

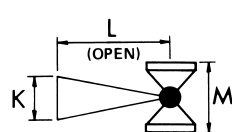

| FRACTIONAL EQUIVALENT | 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.38 | 0.44 | 0.50 | 0.56 | 0.62 | 0.69  | 0.75 | 0.81  | 0.88 | 0.94  |
|-----------------------|------|------|------|------|------|------|------|------|------|------|-------|------|-------|------|-------|
|                       | 1/16 | 1/8  | 3/16 | 1/4  | 5/16 | 3/8  | 7/16 | 1/2  | 9/16 | 5/8  | 11/16 | 3/4  | 13/16 | 7/8  | 15/16 |

# CLASS 150

# BUTT-WELDED PIPING DIMENSIONS

# TABLE D-3

DIMENSIONS IN THIS TABLE INCLUDE 0.06-inch RAISED FACE ON FLANGES

| NOMINAL PIPE SIZE (NPS)   |  |  |             | 2               | 3               | 4                   | 6                 | 8                   | 10                  | 12                  | 14                | 16             | 18              | 20                | 24                    |                |
|---|--|--|-------------|-----------------|-----------------|---------------------|-------------------|---------------------|---------------------|---------------------|-------------------|----------------|-----------------|-------------------|-----------------------|----------------|
| FITTINGS  | STRAIGHT TEE<br>TABLE D-6 FOR REDUCING TEES<br>       |  |             |                 | 2.5             | 3.38                | 4.12              | 5.62                | 7                   | 8.5                 | 10                | 11             | 12              | 13.5              | 15                    | 17             |
|   | Weldolet<br>STANDARD AND EXTRA-STRONG<br>             |  |             | BRANCH DIAMETER |                 | 2                   | 3                 | 4                   |                     |                     |                   |                |                 |                   |                       |                |
|   | REDUCERS<br>CONCENTRIC & ECCENTRIC<br>                |  |             |                 | Swage-Table D-4 | 3.5                 | 4                 | 5.5                 | 6                   | 7                   | 8                 | 13             | 14              | 15                | 20                    | 20             |
|   | 90° LR ELLS<br>REGULAR & REDUCING<br>                 |  |             |                 | 3               | 4.5                 | 6                 | 9                   | 12                  | 15                  | 18                | 21             | 24              | 27                | 30                    | 36             |
|   | 90° SR ELL<br>  |  |             |                 | 2               | 3                   | 4                 | 6                   | 8                   | 10                  | 12                | 14             | 16              | 18                | 20                    | 24             |
|   | 45° ELL (LR)<br>                                      |  |             |                 | 1.38            | 2                   | 2.5               | 3.75                | 5                   | 6.25                | 7.5               | 8.75           | 10              | 11.25             | 12.5                  | 15             |
|   | OFFSET<br>(TWO 45° ELLS)<br>                          |  |             | A<br>B          | 1.94<br>4.69    | 2.81<br>6.81        | 3.56<br>8.56      | 5.31<br>12.81       | 7.06<br>17.06       | 8.81<br>21.31       | 10.62<br>25.62    | 12.38<br>29.88 | 14.12<br>34.12  | 15.94<br>38.44    | 17.69<br>42.69        | 21.19<br>51.19 |
|   | ROLLED-ELL<br>(45° ELL + 90° LR ELL)<br>              |  |             | C<br>D          | 3.12<br>4.50    | 4.62<br>6.62        | 6<br>8.5          | 9<br>12.75          | 12<br>17            | 15<br>21.25         | 18<br>25.5        | 21.06<br>29.81 | 24.06<br>34.06  | 27.06<br>38.31    | 30.06<br>42.56        | 36.06<br>51.06 |
|   | 90° LR ELL + WELDING-NECK<br>RAISED-FACE FLANGE<br> |  |             | E<br>F<br>G     | 5.5<br>6<br>2.5 | 7.25<br>7.5<br>2.75 | 9<br>9<br>3       | 12.5<br>11<br>3.5   | 16<br>13.5<br>4     | 19<br>16<br>4       | 22.5<br>19<br>4.5 | 26<br>21<br>5  | 29<br>23.5<br>5 | 32.5<br>25<br>5.5 | 35.69<br>27.5<br>5.69 | 42<br>32<br>6  |
|   | VALVES   | PLUG<br>SHORT PATTERN: NPS 2-12<br>VENTURI PATTERN: NPS 2-4 & 14-24<br>REGULAR PATTERN: NPS 14-24<br> |             |                 |                 | S<br>V              | S<br>8            | S<br>9              | S<br>10.5           | S<br>11.5           | S<br>13           | S<br>14        | R<br>27         | R<br>30           | R<br>34               | R<br>36        |
| GATE<br>REFER TO TABLE V-1 FOR END-TO-END DIMENSIONS OF GATE VALVES WITH BUTT-WELDING ENDS<br> |  |  | H<br>I<br>J | 8<br>19<br>7    | 10<br>23<br>8   | 12<br>28<br>9       | 14<br>37<br>10.5  | 16<br>47<br>11.5    | 18<br>53<br>13      | 20<br>61<br>14      | 24<br>71<br>15    | 26<br>80<br>16 | 30<br>89<br>17  | 30<br>98<br>18    | 36<br>113<br>20       |                |
| BALL<br>LONG PATTERN: NPS 2-24<br>SHORT PATTERN: NPS 2-16, USE 'J' ABOVE FOR GATE VA<br>       |  |  |             | 7               | 8               | 9                   | 15.5              | 18                  | 21                  | 24                  | 27                | 30             | 34              | 36                | 42                    |                |
| GLOBE<br>DIMENSIONS ALSO APPLY TO GLOBE VALVES WITH BUTT-WELDING ENDS<br>                      |  |  | K<br>L<br>M | 8<br>15<br>8    | 10<br>19<br>9.5 | 12<br>21<br>11.5    | 16<br>26<br>16    | 18<br>33<br>19.5    | 24<br>32<br>24.5    | 36<br>42<br>27.5    | 36<br>49<br>31    |                |                 |                   |                       |                |
| CHECK<br>SWING: NPS 2-24<br>TILTING DISC: NPS 2-14<br>LIFT: NPS 2-4 & 8-14<br>                 |  |  |             | L<br>S<br>T     | L<br>9.5<br>T   | L<br>11.5<br>S<br>T | -<br>14<br>S<br>T | L<br>19.5<br>S<br>T | L<br>24.5<br>S<br>T | L<br>27.5<br>S<br>T | L<br>31<br>S<br>T | S<br>34        | S<br>38.5       | S<br>38.5         | S<br>51               |                |
|   |  |  |             |                 |                 |                     |                   |                     |                     |                     |                   |                |                 |                   |                       |                |
|   |  |  |             |                 |                 |                     |                   |                     |                     |                     |                   |                |                 |                   |                       |                |
|   |  |  |             |                 |                 |                     |                   |                     |                     |                     |                   |                |                 |                   |                       |                |

- DIMENSIONS FOR COMBINATIONS OF FITTINGS AND INSTALLED WELDOLETS DO NOT INCLUDE THE 'WELD GAP' - REFER TO TEXT: SECTION 5.3.5
- DIMENSIONS IN THIS TABLE ARE NOMINAL AND FOR COMBINATIONS OF FITTINGS ARE ROUNDED TO 1/100-inch
- 'H', 'I', 'K' AND 'L' ARE THE LARGEST DIMENSIONS FOR MANUALLY-OPERATED CAST-STEEL VALVES FROM A SELECTION OF MANUFACTURERS
- GUIDELINES FOR THE USE OF GEAR AND POWERED OPERATORS WITH VALVES ARE GIVEN IN SECTION 3.1.2 OF THE TEXT

| FRACTIONAL | 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.38 | 0.44 | 0.50 | 0.56 | 0.62 | 0.69  | 0.75 | 0.81  | 0.88 | 0.94  |
|------------|------|------|------|------|------|------|------|------|------|------|-------|------|-------|------|-------|
| EQUIVALENT | 1/16 | 1/8  | 3/16 | 1/4  | 5/16 | 3/8  | 7/16 | 1/2  | 9/16 | 5/8  | 11/16 | 3/4  | 13/16 | 7/8  | 15/16 |

## SWAGES

**TABLE D-4**

NPS (INCHES)

LARGE END SMALL END

2 ¼-1½

LENGTHS: 6.5

2½ ½-2

LENGTHS: 7.0

3 ½-2½

LENGTHS: 8.0

3½ 2-3

LENGTHS: 8.0

4 1-3½

LENGTHS: 9.0

5 2-4

LENGTHS: 11

6 1½-5

LENGTHS: 12

8 2-6

LENGTHS: 13

10 4-8

LENGTHS: 15

LARGE END SMALL END

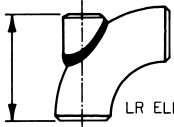
Dimensions in this table are for Mills Iron Works swages, available with ends plain, threaded, bevelled, Victaulic grooved, and in any combination of these terminations

## ELBOLETS: THREADED/SOCKET & BUTT-WELDING

DIMENSIONS IN INCHES

**TABLE D-5**

NOMINAL PIPE SIZE OF MAIN RUN [NPS]

| NPS OF BRANCH | 2   | 3    | 4     | 6     | 8     | 10    | 12    | 14    | 16    | 18    | 20    | 24    |
|---------------|---|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|               | CLASS 3000 THREADED & SOCKET-WELDING* - STD AND XS BUTT-WELDING                   |      |       |       |       |       |       |       |       |       |       |       |
| 1/2           | 3.53  | 5.94 | 7.25  | 10    | 12.66 | 15.38 | 18.03 | 20.12 | 22.75 | 25.41 | 28.06 | 33.34 |
| 3/4           | 4.81  | 6.22 | 7.53  | 10.28 | 12.94 | 15.66 | 18.31 | 20.41 | 23.03 | 25.69 | 28.34 | 33.62 |
| 1             | 5.12  | 6.53 | 7.84  | 10.59 | 13.25 | 15.97 | 18.62 | 20.72 | 23.34 | 26    | 28.66 | 33.94 |
| 1 1/2         | 5.56  | 6.97 | 8.28  | 11.03 | 13.69 | 16.41 | 19.06 | 21.16 | 23.78 | 26.44 | 29.09 | 34.38 |
| 2             | 6.12  | 7.53 | 8.84  | 11.59 | 14.25 | 16.97 | 19.62 | 21.72 | 24.34 | 27    | 29.97 | 34.94 |
| 3             |   | 8.16 | 9.47  | 12.22 | 14.88 | 17.59 | 20.25 | 22.34 | 24.97 | 27.62 | 30.28 | 35.56 |
| 4             |   |      | 10.16 | 12.91 | 15.56 | 18.28 | 20.94 | 23.03 | 25.66 | 28.31 | 30.97 | 36.25 |
| 6             |  |      |       | 14.59 | 17.25 | 19.97 | 22.62 | 24.72 | 27.34 | 30    | 32.66 | 37.94 |
| 8             |   |      |       |       | 18.25 | 20.97 | 23.62 | 25.72 | 28.34 | 31    | 33.66 | 38.94 |
| 10            |   |      |       |       |       | 22.78 | 25.44 | 27.53 | 30.16 | 32.81 | 35.47 | 40.75 |
| 12            |   |      |       |       |       |       | 26.44 | 28.53 | 31.16 | 33.81 | 36.94 | 41.75 |

Data provided by BONNEY FORGE. Dimensions for Elbolets are nominal. Size 2-inch Elbolets are designed to fit the different sizes of run pipe; in sizes larger than 2-inches, each size of Elbolet is designed to fit a range of run pipe sizes.  
\* Threaded and socket-welding Elbolets are not available in sizes 6-inch and larger.

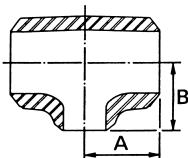
## REDUCING BUTT-WELDING TEES

WEIGHTS: STANDARD and EXTRA-STRONG.  
SCH 160 thru NPS 12. XXS thru NPS 8

**TABLE D-6**

NOMINAL PIPE SIZE OF MAIN RUN [NPS]

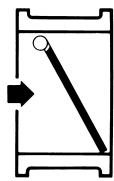
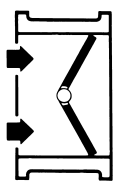
| NPS           | 3    | 4    | 6    | 8    | 10   | 12    | 14    | 16    | 18    | 20    | 24    |
|---------------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|
| DIMENSION 'A' | 3.38 | 4.12 | 5.62 | 7.00 | 8.50 | 10.00 | 11.00 | 12.00 | 13.50 | 15.00 | 17.00 |
| NPS OF BRANCH | 2    | 3    | 4    | 6    | 8    | 10    | 12    | 14    | 16    | 18    | 20    |
|               | 3.00 | 3.50 |      |      |      |       |       |       |       |       |       |
|               |      | 3.88 | 4.88 |      |      |       |       |       |       |       |       |
|               |      |      | 5.12 | 6.12 | 7.25 |       |       |       |       |       |       |
|               |      |      |      | 6.62 | 7.62 | 8.62  | 9.38  | 10.38 |       |       |       |
|               |      |      |      |      | 8.00 | 9.00  | 9.75  | 10.75 | 11.75 | 12.75 |       |
|               |      |      |      |      |      | 9.50  | 10.12 | 11.12 | 12.12 | 13.12 | 15.12 |
|               |      |      |      |      |      |       | 10.62 | 11.62 | 12.62 | 13.62 | 15.62 |
|               |      |      |      |      |      |       |       | 12.00 | 13.00 | 14.00 | 16.00 |
|               |      |      |      |      |      |       |       |       | 13.00 | 14.00 | 16.00 |
|               |      |      |      |      |      |       |       |       |       | 14.50 | 16.50 |
|               |      |      |      |      |      |       |       |       |       |       | 17.00 |



# CHECK VALVES - WAFER-TYPE

## TABLE D-7

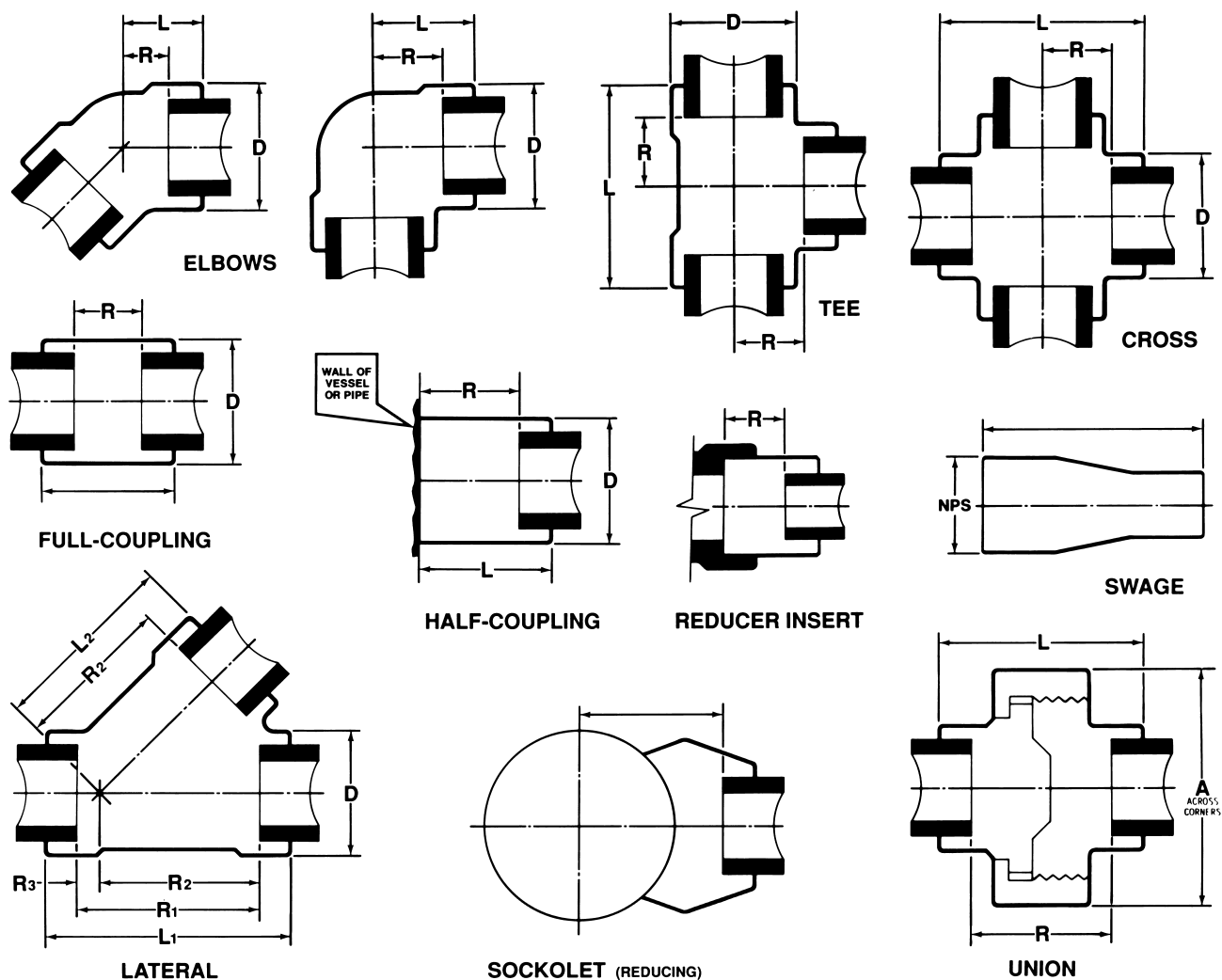
FACE-TO-FACE DIMENSIONS BY CLASS FOR VALVES CONFORMING TO API 594

| NPS | F L A N G E C L A S S E S |       |       |       |       |   |
|-----|---------------------------|-------|-------|-------|-------|---|
|     | 150                       | 300   | 600   | 900   | 1500  | 2500  |
| 2   | 2.38                      | 2.38  | 2.38  | 2.75  | 2.75  | 2.75  |
| 3   | 2.88                      | 2.88  | 2.88  | 3.25  | 3.25  | 3.38  |
| 4   | 2.88                      | 2.88  | 3.12  | 4.00  | 4.00  | 4.12  |
| 6   | 3.88                      | 3.88  | 5.38  | 6.25  | 6.25  | 6.25  |
| 8   | 5.00                      | 5.00  | 6.50  | 8.12  | 8.12  | 8.12  |
| 10  | 5.75                      | 5.75  | 8.38  | 9.50  | 9.75  | 10.00   |
| 12  | 7.12                      | 7.12  | 9.00  | 11.50 | 12.00 | 12.00   |
| 14  | 7.25                      | 8.75  | 10.75 | 14.00 | 14.00 |  <p>SINGLE AND DUAL PLATES</p>  |
| 16  | 7.50                      | 9.12  | 12.00 | 15.12 | 15.12 |   |
| 18  | 8.00                      | 10.38 | 14.25 | 17.75 | 18.44 |   |
| 20  | 8.62                      | 11.50 | 14.50 | 17.75 | 21.00 |   |
| 24  | 8.75                      | 12.50 | 17.25 | 19.50 | 22.00 |   |

# SOCKET WELDING FITTINGS - FORGED STEEL

'R' DIMENSIONS INCLUDE  
EXPANSION GAP - NOTE 1

**TABLE D-8**



| PRESSURE CLASS                  |   | 3000 |      |      |       |      | 6000 |      |      |       |      | 9000<br>[Bonney Forge] |      |      |       |      |
|---------------------------------|---|------|------|------|-------|------|------|------|------|-------|------|------------------------|------|------|-------|------|
| NOMINAL PIPE SIZE<br>(NPS)      |   | 1/2  | 3/4  | 1    | 1 1/2 | 2    | 1/2  | 3/4  | 1    | 1 1/2 | 2    | 1/2                    | 3/4  | 1    | 1 1/2 | 2    |
| 45 ELL                          | R | 0.50 | 0.56 | 0.62 | 0.88  | 1.06 | 0.56 | 0.62 | 0.75 | 1.06  | 1.19 | 0.69                   | 0.81 | 0.88 | 1.06  | 1.19 |
|                                 | L | 1.00 | 1.12 | 1.25 | 1.38  | 1.69 | 1.12 | 1.25 | 1.31 | 1.69  | 1.75 | 1.25                   | 1.31 | 1.38 | 1.75  | 2.06 |
| 90 ELL, CROSS<br>& STRAIGHT TEE | R | 0.69 | 0.81 | 0.94 | 1.31  | 1.56 | 0.81 | 0.94 | 1.12 | 1.56  | 1.69 | 1.06                   | 1.19 | 1.31 | 1.56  | 2.19 |
|                                 | L | 1.12 | 1.31 | 1.50 | 2.00  | 2.38 | 1.31 | 1.50 | 1.75 | 2.38  | 2.50 | 1.50                   | 1.75 | 2.00 | 2.50  | 3.25 |

| FULL-COUPLING           |                            | R     | 0.50 | 0.50 | 0.62 | 0.62 | 0.88 | 0.50 | 0.50 | 0.62 | 0.62 | 0.88 | 0.50 | 0.50 | 0.62 | 0.62 | 0.88 |
|-------------------------|----------------------------|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                         |                            | L     | 1.38 | 1.50 | 1.75 | 2.00 | 2.50 | 1.38 | 1.50 | 1.75 | 2.00 | 2.50 | 1.38 | 1.50 | 1.75 | 2.00 | 2.50 |
| HALF-COUPLING           |                            | R     | 0.94 | 1.00 | 1.19 | 1.31 | 1.69 | 0.94 | 1.00 | 1.19 | 1.31 | 1.69 | 0.94 | 1.00 | 1.19 | 1.31 | 1.75 |
|                         |                            | L     | 1.38 | 1.50 | 1.75 | 2.00 | 2.50 | 1.38 | 1.50 | 1.75 | 2.00 | 2.50 | 1.38 | 1.50 | 1.75 | 2.00 | 2.50 |
| REDUCER<br>INSERT       | 1/2                        | R     |      | 0.94 | 0.69 | 0.88 | 1.06 |      | 1.12 | 1.19 | 1.12 | 1.19 |      | 1.25 | 1.19 | 1.06 | 1.19 |
|                         | 3/4                        |       |      |      | 1.00 | 0.81 | 1.00 |      |      | 1.19 | 1.06 | 1.12 |      |      | 1.31 | 1.06 | 1.12 |
|                         | 1                          |       |      |      |      | 0.75 | 0.94 |      |      |      | 1.25 | 1.06 |      |      |      | 1.44 | 1.06 |
|                         | 1 1/2                      |       |      |      |      |      | 1.31 |      |      |      |      | 1.94 |      |      |      |      | 2.12 |
| [Bonney Forge]          |                            |       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| LATERAL                 |                            | R1    | 2.12 | 2.56 | 3.00 | 4.00 | 4.81 | 2.56 | 3.00 | 3.56 | 4.81 | 7.38 | 3.12 | 3.69 | 4.12 | 5.00 |      |
|                         |                            | R2    | 1.69 | 2.06 | 2.44 | 3.25 | 3.94 | 2.06 | 2.44 | 2.88 | 3.94 | 6.06 | 2.50 | 2.94 | 3.31 | 4.19 |      |
|                         |                            | R3    | 0.44 | 0.50 | 0.56 | 0.75 | 0.88 | 0.50 | 0.56 | 0.69 | 0.88 | 1.31 | 0.62 | 0.75 | 0.81 | 0.81 |      |
|                         |                            | L1    | 3.00 | 3.56 | 4.12 | 5.38 | 6.44 | 3.56 | 4.12 | 4.81 | 6.44 | 9.00 | 4.12 | 4.81 | 5.38 | 6.62 |      |
|                         |                            | L2    | 2.12 | 2.56 | 3.00 | 3.94 | 4.75 | 2.56 | 3.00 | 3.50 | 4.75 | 6.88 | 3.00 | 3.50 | 3.94 | 5.00 |      |
| [Bonney Forge & Ladish] |                            |       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| DIAMETER                |                            | D     | 1.31 | 1.56 | 1.88 | 2.50 | 3.06 | 1.56 | 1.84 | 2.25 | 3.06 | 3.62 | 1.84 | 2.22 | 2.50 | 3.38 | 4.00 |
| SOCKOLET<br>(REDUCING)  | B<br>R<br>A<br>N<br>C<br>H | 1/2   |      | 1.15 | 1.28 | 1.58 | 1.81 |      | 1.46 | 1.60 | 1.89 | 2.12 |      | 1.43 | 1.57 | 1.86 | 2.10 |
|                         |                            | 3/4   |      |      | 1.28 | 1.58 | 1.81 |      |      | 1.60 | 1.89 | 2.12 |      |      | 1.66 | 1.95 | 2.19 |
|                         |                            | 1     |      |      |      | 1.79 | 2.03 |      |      |      | 1.95 | 2.19 |      |      |      | 2.04 | 2.28 |
|                         |                            | 1 1/2 |      |      |      |      | 2.00 |      |      |      |      | 2.12 |      |      |      |      | 2.41 |
| [Bonney Forge]          |                            |       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| UNION                   |                            | R     | 1.22 | 1.28 | 1.50 | 2.00 | 2.19 | 1.28 | 1.50 | 1.83 | 2.19 | 2.50 |      |      |      |      |      |
|                         |                            | L     | 2.00 | 2.31 | 2.44 | 3.00 | 3.50 | 2.31 | 2.44 | 2.88 | 3.50 | 4.12 |      |      |      |      |      |
|                         |                            | A     | 1.94 | 2.38 | 2.78 | 3.72 | 4.42 | 2.38 | 2.78 | 3.36 | 4.42 | 5.23 |      |      |      |      |      |
| [Bonney Forge]          |                            |       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| SWAGE                   |                            |       | 2.75 | 3.00 | 3.50 | 4.50 | 6.50 | 2.75 | 3.00 | 3.50 | 4.50 | 6.50 | 2.75 | 3.00 | 3.50 | 4.50 | 6.50 |

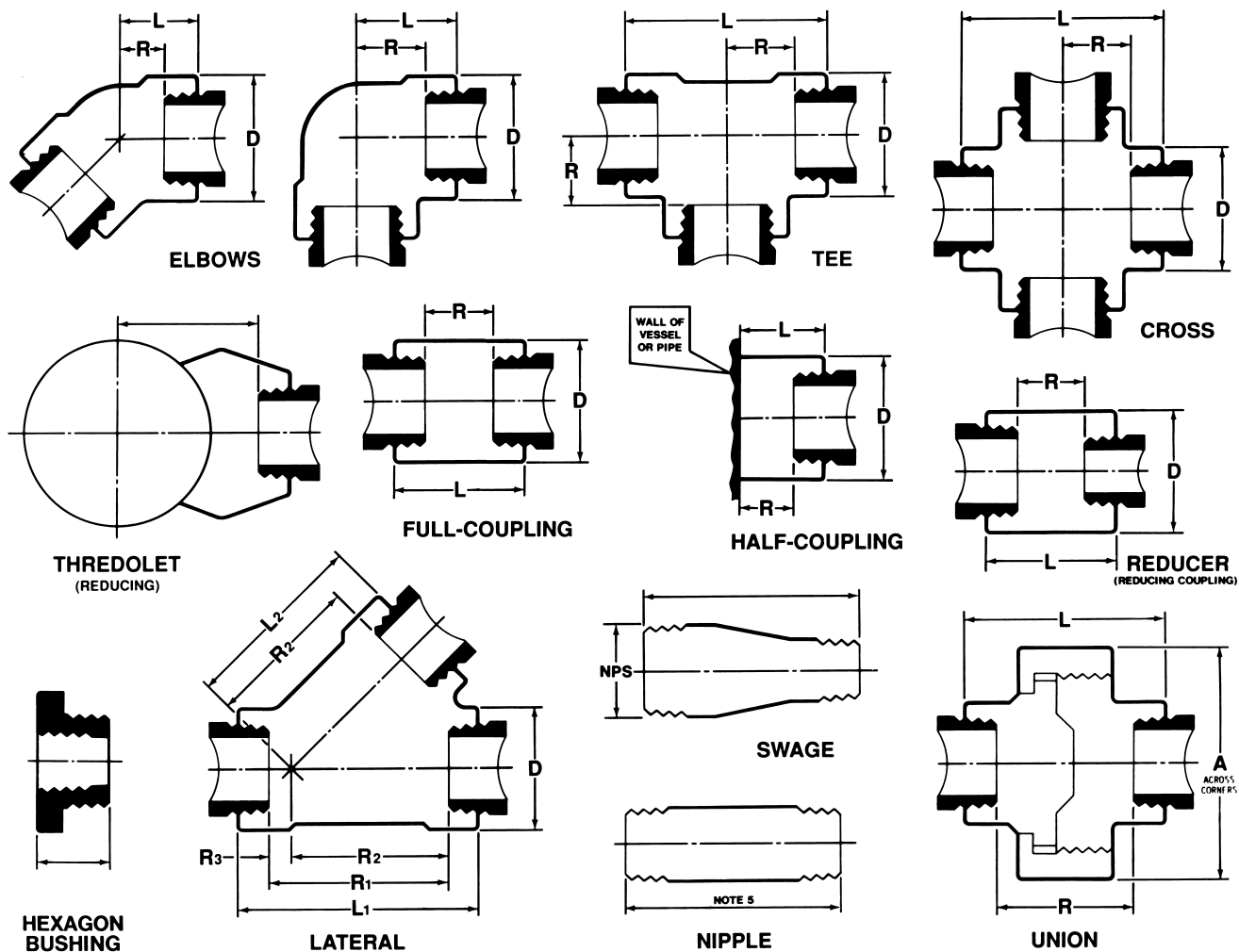
- (1) 'R' DIMENSIONS ('REMOVED RUN' OF PIPE) HAVE BEEN ROUNDED TO 1/100-INCH AND INCLUDE 0.06-INCH EXPANSION GAP(S) FOR WELDING. REFER TO 'SOCKET-WELDED PIPING' - CHART 2.2
- (2) DIMENSIONS ARE FROM THE FOLLOWING SUPPLIERS' DATA: BONNEY FORGE, ITT GRINNEL, LADISH AND VOGT
- (3) UNLESS THE SUPPLIER IS STATED, 'L' & 'D' DIMENSIONS ARE THE LARGEST QUOTED BY BONNEY FORGE, ITT GRINNEL, LADISH AND VOGT
- (4) FITTINGS CONFORM TO ANSI B16.11, EXCEPT LATERALS AND REDUCER INSERTS, WHICH ARE MADE TO MANUFACTURERS' STANDARDS
- (5) FOR INFORMATION ON THE BORE DIAMETER AND RATING OF FITTINGS, REFER TO 'SOCKET-WELDED PIPING' - CHART 2.2
- (6) UNIONS CONFORM TO MSS-SP-83
- (7) DIMENSIONS FOR INSTALLED SOCKOLETS EXCLUDE THE 'ROOT GAP' - REFER TO 'DIMENSIONING SPOOLS (WELDED ASSEMBLIES)' - 5.3.5

|            |      |      |      |      |      |      |      |      |      |      |       |      |       |      |       |
|------------|------|------|------|------|------|------|------|------|------|------|-------|------|-------|------|-------|
| FRACTIONAL | 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.38 | 0.44 | 0.50 | 0.56 | 0.62 | 0.69  | 0.75 | 0.81  | 0.88 | 0.94  |
| EQUIVALENT | 1/16 | 1/8  | 3/16 | 1/4  | 5/16 | 3/8  | 7/16 | 1/2  | 9/16 | 5/8  | 11/16 | 3/4  | 13/16 | 7/8  | 15/16 |

# THREADED FITTINGS - FORGED STEEL

DIMENSIONS IN INCHES

TABLE D-9



| PRESSURE CLASS               |   | 2000 |      |      |       |      | 3000 |      |      |       |      | 6000 |      |      |       |      |
|------------------------------|---|------|------|------|-------|------|------|------|------|-------|------|------|------|------|-------|------|
| NOMINAL PIPE SIZE (NPS)      |   | 1/2  | 3/4  | 1    | 1 1/2 | 2    | 1/2  | 3/4  | 1    | 1 1/2 | 2    | 1/2  | 3/4  | 1    | 1 1/2 | 2    |
| 45 ELL                       | R | 0.44 | 0.50 | 0.50 | 0.69  | 1.00 | 0.56 | 0.62 | 0.62 | 1.00  | 1.00 | 0.69 | 0.75 | 0.69 | 1.06  | 1.31 |
|                              | L | 0.94 | 1.06 | 1.19 | 1.38  | 1.75 | 1.06 | 1.19 | 1.31 | 1.69  | 1.75 | 1.19 | 1.31 | 1.38 | 1.75  | 2.06 |
| 90 ELL, CROSS & STRAIGHT TEE | R | 0.62 | 0.75 | 0.81 | 1.31  | 1.62 | 0.81 | 0.94 | 1.06 | 1.69  | 1.75 | 1.00 | 1.19 | 1.31 | 1.81  | 2.50 |
|                              | L | 1.12 | 1.31 | 1.50 | 2.00  | 2.38 | 1.31 | 1.50 | 1.75 | 2.38  | 2.50 | 1.50 | 1.75 | 2.00 | 2.50  | 3.25 |
| FULL-COUPLING                | R |      |      |      |       |      | 0.88 | 0.88 | 1.00 | 1.75  | 1.88 | 0.88 | 0.88 | 1.00 | 1.75  | 1.88 |
|                              | L |      |      |      |       |      | 1.88 | 2.00 | 2.38 | 3.12  | 3.38 | 1.88 | 2.00 | 2.38 | 3.12  | 3.38 |

| HALF-COUPLING           |                            | R                          |      |      |      |      |      | 0.44 | 0.44 | 0.50 | 0.88 | 0.94 | 0.44 | 0.44 | 0.50 | 0.88 | 0.94 |
|-------------------------|----------------------------|----------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                         |                            | L                          |      |      |      |      |      | 0.94 | 1.00 | 1.19 | 1.56 | 1.69 | 0.94 | 1.00 | 1.19 | 1.56 | 1.69 |
| REDUCER                 | 1/2                        | R                          |      |      |      |      |      |      | 0.94 | 1.19 | 1.94 | 2.12 |      | 0.94 | 1.19 | 1.94 | 2.12 |
|                         | 3/4                        |                            |      |      |      |      |      |      |      | 1.12 | 1.88 | 2.06 |      |      | 1.12 | 1.88 | 2.06 |
|                         | 1                          |                            |      |      |      |      |      |      |      |      | 1.75 | 1.94 |      |      |      | 1.75 | 1.94 |
|                         | 1 1/2                      |                            |      |      |      |      |      |      |      |      |      | 1.94 |      |      |      |      | 1.94 |
|                         |                            | L                          |      |      |      |      |      |      | 2.00 | 2.38 | 3.12 | 3.38 |      | 2.00 | 2.38 | 3.12 | 3.38 |
| LATERAL                 |                            | R1                         | 2.07 | 2.49 | 2.82 | 4.12 | 5.06 | 2.62 | 3.07 | 3.56 | 5.19 | 7.50 | 3.19 | 3.81 | 4.12 | 7.62 | 7.62 |
|                         |                            | R2                         | 1.66 | 2.03 | 2.34 | 3.31 | 4.06 | 2.09 | 2.47 | 2.87 | 4.12 | 6.12 | 2.53 | 3.00 | 3.31 | 6.19 | 6.25 |
|                         |                            | R3                         | 0.41 | 0.47 | 0.47 | 0.81 | 1.00 | 0.53 | 0.60 | 0.69 | 1.06 | 1.38 | 0.66 | 0.81 | 0.81 | 1.44 | 1.38 |
|                         |                            | L1                         | 3.07 | 3.62 | 4.19 | 5.50 | 6.56 | 3.62 | 4.19 | 4.94 | 6.56 | 9.00 | 4.19 | 4.94 | 5.50 | 9.00 | 9.12 |
|                         |                            | [Bonney Forge & Ladish] L2 | 2.16 | 2.59 | 3.03 | 4.00 | 4.81 | 2.59 | 3.03 | 3.56 | 4.81 | 6.88 | 3.03 | 3.56 | 4.00 | 6.88 | 7.00 |
| DIAMETER                |                            | D                          | 1.31 | 1.56 | 1.84 | 2.59 | 3.06 | 1.56 | 1.84 | 2.25 | 3.06 | 3.62 | 1.84 | 2.25 | 2.50 | 3.62 | 4.31 |
| THREDOLET<br>(REDUCING) | B<br>R<br>A<br>N<br>C<br>H | 1/2                        |      |      |      |      |      |      | 1.03 | 1.16 | 1.45 | 1.69 |      | 1.28 | 1.41 | 1.70 | 1.94 |
|                         |                            | 3/4                        |      |      |      |      |      |      |      | 1.16 | 1.45 | 1.69 |      |      | 1.53 | 1.83 | 2.06 |
|                         |                            | 1                          |      |      |      |      |      |      |      |      | 1.58 | 1.81 |      |      |      | 1.83 | 2.06 |
|                         |                            | 1 1/2                      |      |      |      |      |      |      |      |      |      | 1.88 |      |      |      |      | 2.19 |
| UNION                   |                            | R                          |      |      |      |      |      | 1.00 | 1.19 | 1.06 | 1.64 | 1.95 | 1.27 | 1.31 | 1.50 | 2.06 | 2.58 |
|                         |                            | L                          |      |      |      |      |      | 2.00 | 2.31 | 2.44 | 3.01 | 3.45 | 2.27 | 2.44 | 2.88 | 3.44 | 4.08 |
|                         |                            | A                          |      |      |      |      |      | 1.94 | 2.41 | 2.78 | 3.72 | 4.42 | 2.41 | 2.75 | 3.36 | 4.42 | 5.23 |
| HEX BUSH                |                            |                            | 0.94 | 1.00 | 1.06 | 1.31 | 1.44 | 0.94 | 1.00 | 1.06 | 1.31 | 1.44 | 0.94 | 1.00 | 1.06 | 1.31 | 1.44 |
| SWAGE                   |                            |                            | 2.75 | 3.00 | 3.50 | 4.50 | 6.50 | 2.75 | 3.00 | 3.50 | 4.50 | 6.50 | 2.75 | 3.00 | 3.50 | 4.50 | 6.50 |
| THREAD ENGAGEMENT       |                            |                            | 0.50 | 0.56 | 0.69 | 0.69 | 0.75 | 0.50 | 0.56 | 0.69 | 0.69 | 0.75 | 0.50 | 0.56 | 0.69 | 0.69 | 0.75 |

- (1) 'R' DIMENSIONS ('REMOVED RUN' OF PIPE) ARE BASED ON NORMAL THREAD ENGAGEMENT BETWEEN MALE AND FEMALE THREADS TO MAKE TIGHT JOINTS - ROUNDED TO 1/100-inch
- (2) DIMENSIONS FOR FITTINGS ARE FROM THE FOLLOWING SUPPLIERS' DATA: BONNEY FORGE, ITT GRINNELL, LADISH AND VOGT
- (3) UNLESS THE SUPPLIER IS STATED, 'L' & 'D' DIMENSIONS ARE THE LARGEST QUOTED BY BONNEY FORGE, ITT GRINNELL, LADISH AND VOGT
- (4) FITTINGS CONFORM TO ANSI B16.11, EXCEPT LATERALS, WHICH ARE MADE TO MANUFACTURERS' STANDARDS. UNIONS CONFORM TO MSS-SP-83
- (5) FOR SIZES AND AVAILABILITIES OF PIPE NIPPLES, REFER TO 'MALLEABLE-IRON PIPE FITTINGS' - TABLE D-11
- (6) DIMENSIONS FOR INSTALLED THREDOLETS EXCLUDE THE 'ROOT GAP' - REFER TO 'DIMENSIONING SPOOLS (WELDED ASSEMBLIES)' - 5.3.5

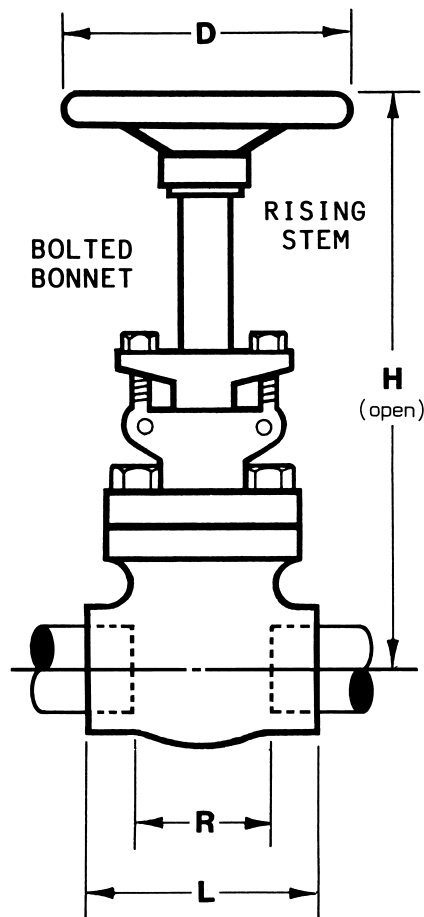
|            |      |      |      |      |      |      |      |      |      |      |       |      |       |      |       |
|------------|------|------|------|------|------|------|------|------|------|------|-------|------|-------|------|-------|
| FRACTIONAL | 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.38 | 0.44 | 0.50 | 0.56 | 0.62 | 0.69  | 0.75 | 0.81  | 0.88 | 0.94  |
| EQUIVALENT | 1/16 | 1/8  | 3/16 | 1/4  | 5/16 | 3/8  | 7/16 | 1/2  | 9/16 | 5/8  | 11/16 | 3/4  | 13/16 | 7/8  | 15/16 |

# CLASS 800 VALVES

API CLASS 800 FORGED-STEEL  
GATE, GLOBE & CHECK VALVES

## TABLE D - 10

DATA: SMITH VALVE CORPORATION  
GATE VALVES: FULL PORT  
GLOBE VALVES: CONVENTIONAL PORT



'R' is the 'REMOVED RUN' of  
pipe occupied by the valve

### VALVES WITH THREADED ENDS

| NPS                   |    | 1/2  | 3/4  | 1    | 1 1/2 | 2     |
|-----------------------|----|------|------|------|-------|-------|
| G<br>A<br>T<br>E      | D  | 4.00 | 4.00 | 5.50 | 6.62  | 6.62  |
|                       | H  | 6.38 | 7.25 | 8.56 | 11.00 | 12.50 |
|                       | L  | 3.50 | 3.88 | 4.25 | 5.50  | 5.69  |
|                       | R  | 2.50 | 2.75 | 2.88 | 4.12  | 4.19  |
| G<br>L<br>O<br>B<br>E | D  | 4.00 | 4.00 | 4.00 | 4.62  | 6.62  |
|                       | H  | 6.38 | 6.56 | 6.81 | 8.12  | 10.12 |
|                       | L* | 3.25 | 3.50 | 4.50 | 6.25  | 7.25  |
|                       | R* | 2.25 | 2.38 | 3.12 | 4.88  | 5.75  |

'R' dimensions are based on normal  
thread engagement for tight joints

\* These dimensions also apply to horizontal lift-check valves

### VALVES WITH SOCKET ENDS

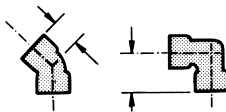
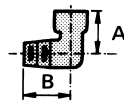

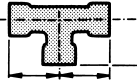
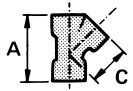
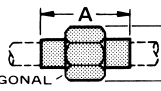
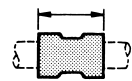
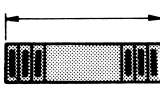
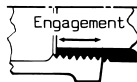
| NPS                   |    | 1/2  | 3/4  | 1    | 1 1/2 | 2     |
|-----------------------|----|------|------|------|-------|-------|
| G<br>A<br>T<br>E      | D  | 4.00 | 4.00 | 5.50 | 6.62  | 6.62  |
|                       | H  | 6.38 | 7.25 | 8.56 | 11.00 | 12.50 |
|                       | L  | 3.50 | 3.88 | 4.25 | 5.50  | 5.69  |
|                       | R  | 2.00 | 2.25 | 2.75 | 3.12  | 3.75  |
| G<br>L<br>O<br>B<br>E | D  | 4.00 | 4.00 | 4.00 | 4.62  | 6.62  |
|                       | H  | 6.38 | 6.56 | 6.81 | 8.12  | 10.12 |
|                       | L* | 3.25 | 3.50 | 4.50 | 6.25  | 7.25  |
|                       | R* | 2.38 | 2.50 | 3.38 | 4.88  | 5.62  |

'R' dimensions include 0.06-inch expansion  
gaps for welding. Refer to text: Chart 2.2

# THREADED FITTINGS - MALLEABLE-IRON

DIMENSIONS ROUNDED  
TO 1/100-inch

TABLE D-11

| PRESSURE CLASS         |   | 150   |   |      |       |      |      | 300  |      |      |       |      |      |      |      |
|------------------------|---|---|---|------|-------|------|------|------|------|------|-------|------|------|------|------|
| NOMINAL PIPE SIZE [IN] |   | 1/2   | 3/4   | 1    | 1 1/2 | 2    | 3    | 1/2  | 3/4  | 1    | 1 1/2 | 2    | 3    |      |      |
| 45° ELL                |    | 0.88  | 1.0   | 1.12 | 1.44  | 1.69 | 2.19 | 1.0  | 1.12 | 1.31 | 1.69  | 2.0  | 2.5  |      |      |
| 90° ELL                |   | 1.12  | 1.31  | 1.5  | 1.94  | 2.25 | 3.06 | 1.25 | 1.44 | 1.62 | 2.12  | 2.5  | 3.38 |      |      |
| 90° STREET ELL         |    | 1.12  | 1.31  | 1.5  | 1.94  | 2.25 | 3.06 | 1.25 | 1.44 | 1.62 | 2.12  | 2.5  | 3.38 |      |      |
|                        |   | 1.62  | 1.88  | 2.12 | 2.69  | 3.25 | 4.5  | 2.0  | 2.19 | 2.56 | 3.12  | 3.69 | 5.12 |      |      |
| RETURN BEND            |    | CLOSE   | 1.0   | 1.25 | 1.5   | 2.19 | 2.62 |      |      |      |       |      |      |      |      |
|                        |   | MEDIUM  | 1.25  | 1.5  | 1.88  | 2.5  | 3.0  |      |      |      |       |      |      |      |      |
|                        |   | OPEN  | 1.5   | 2.0  | 2.5   | 3.5  | 4.0  |      |      |      |       |      |      |      |      |
| STRAIGHT TEE           | (These data also apply to the center-to-end dimension for straight cross.)<br> | 1.12  | 1.31  | 1.5  | 1.94  | 2.25 | 3.06 | 1.25 | 1.44 | 1.62 | 2.12  | 2.5  | 3.38 |      |      |
| LATERAL                |    | A   | 2.31  | 2.81 | 3.31  | 4.38 | 5.19 | 7.25 |      |      |       |      |      |      |      |
|                        |   | C   | 1.69  | 2.06 | 2.44  | 3.25 | 3.94 | 5.56 |      |      |       |      |      |      |      |
| UNION                  | <br>OCTAGONAL  | SEATS   | GRINNELL: COPPER<br>ALLOY-TO-IRON   | 1.94 | 2.06  | 2.44 | 2.75 | 2.94 | 3.75 | 2.06 | 2.25  | 2.56 | 3.00 | 3.38 | 4.25 |
|                        |   | A   | STOCKHAM:<br>BRASS-TO-IRON<br>OR ALL-IRON   | 1.81 | 2.0   | 2.19 | 2.62 | 3.06 | 3.88 | 1.94 | 2.25  | 2.44 | 3.00 | 3.88 | 4.94 |
| COUPLING               |    | 1.31  | 1.5   | 1.69 | 2.12  | 2.5  | 3.19 | 1.88 | 2.12 | 2.38 | 2.88  | 3.62 | 4.12 |      |      |
| NIPPLE                 | <br>CARBON-STEEL<br>(TANK NIPPLES ARE 6-IN. LONG)                            | CLOSE NIPPLE  | 1.12  | 1.38 | 1.5   | 1.75 | 2.0  | 2.62 | 1.12 | 1.38 | 1.5   | 1.75 | 2.0  | 2.62 |      |
|                        |   | AVAILABILITIES<br>OF SHORT AND<br>LONG NIPPLES  | AVAILABLE IN 2, 2 1/2, 3, 3 1/2, 4, 4 1/2, 5<br>5 1/2, 6, 7, 8, 9, 10, 11 & 12 INCH LENGTHS<br>(1/2 and 3/4 NPS nipples are also available 1 1/2 inches long) |      |       |      |      |      |      |      |       |      |      |      |      |
| SWAGE                  | MILLS<br>IRON<br>WORKS<br>CARBON-STEEL  | NPS   | 2.75  | 3.0  | 3.5   | 4.5  | 6.5  | 8.0  | 2.75 | 3.0  | 3.5   | 4.5  | 6.5  | 8.0  |      |
| REDUCER                | NPS   | 1.25  | 1.44  | 1.69 | 2.31  | 2.81 | 3.69 | 1.69 | 1.75 | 2.0  | 2.69  | 3.19 | 4.06 |      |      |
| THREAD ENGAGEMENT      | TAPER<br>TAPER  | Engagement<br> | 0.5   | 0.56 | 0.69  | 0.69 | 0.75 | 1.0  | 0.5  | 0.56 | 0.69  | 0.69 | 0.75 | 1.0  |      |

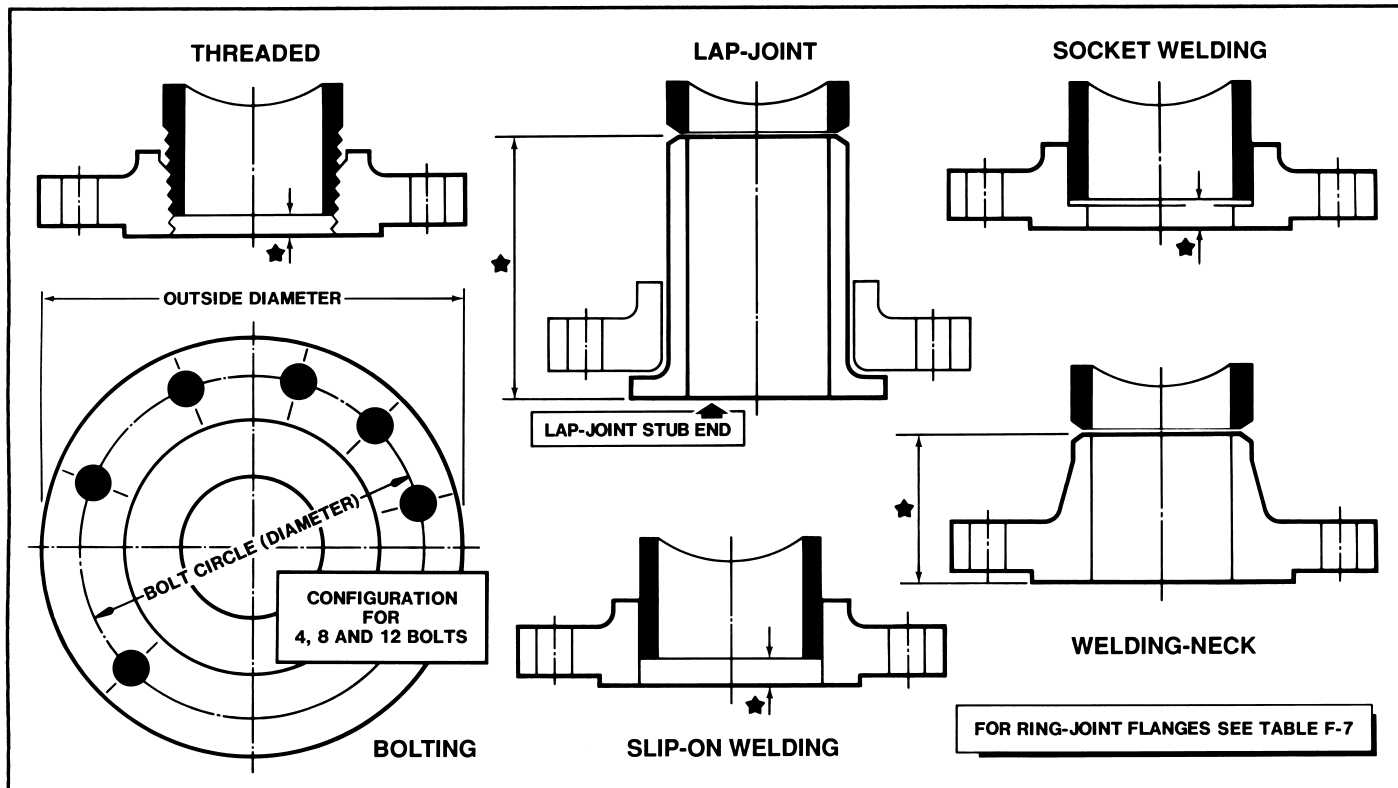
DIMENSIONS IN THIS TABLE ARE FOR BANDED FITTINGS AND CONFORM TO ANSI STANDARD B16.3, AND FEDERAL SPECIFICATION WW-P-521. UNIONS CONFORM TO ANSI B16.39. DATA FROM ITT GRINNELL CORPORATION AND STOCKHAM VALVES AND FITTINGS

# FORGED-STEEL FLANGES & LAP-JOINT STUB-ENDS


FLANGE CLASSES  
150-2500

TABLES F

DIMENSIONS IN INCHES



## NOTES


- [1] FLANGE DIMENSIONS: ANSI STANDARD B16.5 AND MANUFACTURERS' DATA
- [2] BLIND FLANGES: DATA FOR FLANGE DIAMETERS AND BOLTING IN THESE TABLES ALSO APPLIES TO BLIND FLANGES
- [3] REDUCING FLANGES: AVAILABLE IN SLIP-ON, THREADED AND WELDING-NECK TYPES
- [4] LAP-JOINT STUB-ENDS: ANSI B16.9 (Long Pattern) & MSS SP-43 (Short Pattern)
- [5]  STUDBOLT THREAD LENGTHS FOR LAP-JOINTS

| FLANGE COMBINATION                                     | FLANGE CLASS | INCREASE IN STUDBOLT LENGTH OVER LENGTHS IN TABLES F-1 thru F-6 |
|--|--------------|---|
| Lapped to non-lapped                                   | 150 or 300   | Thickness of lap  |
|  | Over 300     | Thickness of lap minus 1/4"                                     |
| Lapped to lapped                                       | 150 - 2500   | Thickness of two laps   |
| Thickness of lap = Thickness of pipe wall + 0" + 0.06" |              |   |

# CLASS 150 FLANGE DATA

- DIMENSIONS INCLUDE 0.06" RAISED FACE ON FLANGES (except lap-joint)
- DIMENSIONS INCLUDE 0.06" GAP FOR WELDING - REFER TO CHART 2.2

TABLE F-1

| NOMINAL PIPE SIZE: NPS                             |   |                    | 1/2  | 3/4                                | 1    | 1 1/2 | 2    | 3    | 4    | 6    | 8    | 10    | 12   | 14                       | 16   | 18 | 20   | 24   |    |    |
|--|---|--------------------|------|------------------------------------|------|-------|------|------|------|------|------|-------|------|--------------------------|------|----|------|------|----|----|
| OUTSIDE DIAMETER                                   |   |                    | 3.5  | 3.88                               | 4.25 | 5     | 6    | 7.5  | 9    | 11   | 13.5 | 16    | 19   | 21                       | 23.5 | 25 | 27.5 | 32   |    |    |
| F<br>L<br>A<br>N<br>G<br>E<br><br>T<br>Y<br>P<br>E | <br>END OF<br>PIPE TO<br>FACE OF<br>FLANGE<br>or LAP<br>JOINT<br>STUB<br>END • | WELD-NECK          |      | 1.88                               | 2.06 | 2.19  | 2.44 | 2.5  | 2.75 | 3    | 3.5  | 4     | 4    | 4.5                      | 5    | 5  | 5.5  | 5.69 | 6  |    |
|  |   | SLIP-ON            |      | Wall thickness of pipe + 0.06-inch |      |       |      |      |      |      |      |       |      |                          |      |    |      |      |    |    |
|  |   | SOCKET ••          |      | 0.31                               | 0.25 | 0.25  | 0.31 | 0.38 | 0.44 |      |      |       |      |                          |      |    |      |      |    |    |
|  |   | THREADED           |      | 0.06                               | 0.06 | 0     | 0.25 | 0.31 | 0.19 | 0.25 | 0.38 | 0.44  | 0.50 | 0.56                     |      |    |      |      |    |    |
|  |   | L-J<br>STUB<br>END | ANSI | 3                                  | 3    | 4     | 4    | 6    | 6    | 6    | 8    | 8     | 10   | 10                       | 12   | 12 | 12   | 12   | 12 | 12 |
|  |   |                    | MSS  | 2                                  | 2    | 2     | 2    | 2.5  | 2.5  | 3    | 3.5  | 4     | 5    | 6                        | 6    | 6  | 6    | 6    | 6  | 6  |
| BORE: WELD-NECK & SOCKET                           |   |                    | 0.62 | 0.82                               | 1.05 | 1.61  | 2.07 | 3.07 | 4.03 | 6.07 | 7.98 | 10.02 | 12   | [Order to match pipe ID] |      |    |      |      |    |    |

|                                 |   |    |      |      |      |      |      |     |     |     |       |       |      |       |       |       |       |       |
|---------------------------------|---|----|------|------|------|------|------|-----|-----|-----|-------|-------|------|-------|-------|-------|-------|-------|
| B<br>O<br>L<br>T<br>I<br>N<br>G | BOLTS PER FLANGE  |    | 4    | 4    | 4    | 4    | 4    | 4   | 8   | 8   | 8     | 12    | 12   | 12    | 16    | 16    | 20    | 20    |
|                                 | BOLT CIRCLE DIAMETER                                    |    | 2.38 | 2.75 | 3.12 | 3.88 | 4.75 | 6   | 7.5 | 9.5 | 11.75 | 14.25 | 17   | 18.75 | 21.25 | 22.75 | 25    | 29.5  |
|                                 | DIAMETER OF BOLT  |    | 1/2  | 1/2  | 1/2  | 1/2  | 5/8  | 5/8 | 5/8 | 3/4 | 3/4   | 7/8   | 7/8  | 1     | 1     | 1 1/8 | 1 1/8 | 1 1/4 |
|                                 | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5 | RF | 2.25 | 2.5  | 2.5  | 2.75 | 3.25 | 3.5 | 3.5 | 4   | 4.25  | 4.5   | 4.75 | 5.25  | 5.25  | 5.75  | 6.25  | 6.75  |
|                                 |   | RJ | -    | -    | 3    | 3.25 | 3.75 | 4   | 4   | 4.5 | 4.75  | 5     | 5.25 | 5.75  | 5.75  | 6.25  | 6.75  | 7.25  |

# CLASS 300 FLANGE DATA

- DIMENSIONS INCLUDE 0.06" RAISED FACE ON FLANGES (except lap-joint)
- DIMENSIONS INCLUDE 0.06" GAP FOR WELDING - REFER TO CHART 2.2


TABLE F-2

| NOMINAL PIPE SIZE: NPS                             |   |                    | 1/2  | 3/4                                | 1    | 1 1/2 | 2    | 3    | 4    | 6     | 8    | 10    | 12    | 14                       | 16    | 18    | 20    | 24    |      |
|--|---|--------------------|------|------------------------------------|------|-------|------|------|------|-------|------|-------|-------|--------------------------|-------|-------|-------|-------|------|
| OUTSIDE DIAMETER                                   |   |                    | 3.75 | 4.62                               | 4.88 | 6.12  | 6.5  | 8.25 | 10   | 12.5  | 15   | 17.5  | 20.5  | 23                       | 25.5  | 28    | 30.5  | 36    |      |
| F<br>L<br>A<br>N<br>G<br>E<br><br>T<br>Y<br>P<br>E | ★<br>END OF<br>PIPE TO<br>FACE OF<br>FLANGE<br>or LAP<br>JOINT<br>STUB<br>END • | WELD-NECK          |      | 2.06                               | 2.25 | 2.44  | 2.69 | 2.75 | 3.12 | 3.38  | 3.88 | 4.38  | 4.62  | 5.12                     | 5.62  | 5.75  | 6.25  | 6.38  | 6.62 |
|  |   | SLIP-ON            |      | Wall thickness of pipe + 0.06-inch |      |       |      |      |      |       |      |       |       |                          |       |       |       |       |      |
|  |   | SOCKET ••          |      | 0.56                               | 0.62 | 0.62  | 0.62 | 0.69 | 0.94 |       |      |       |       |                          |       |       |       |       |      |
|  |   | THREADED           |      | 0.06                               | 0.06 | 0     | 0.25 | 0.44 | 0.25 | 0.38  | 0.62 | 0.69  | 0.75  | 0.75                     |       |       |       |       |      |
|  |   | L-J<br>STUB<br>END | ANSI | 3                                  | 3    | 4     | 4    | 6    | 6    | 6     | 8    | 8     | 10    | 10                       | 12    | 12    | 12    | 12    | 12   |
|  |   |                    | MSS  | 2                                  | 2    | 2     | 2    | 2.5  | 2.5  | 3     | 3.5  | 4     | 5     | 6                        | 6     | 6     | 6     | 6     | 6    |
| BORE: WELD-NECK & SOCKET                           |   |                    | 0.62 | 0.82                               | 1.05 | 1.61  | 2.07 | 3.07 | 4.03 | 6.07  | 7.98 | 10.02 | 12    | [Order to match pipe ID] |       |       |       |       |      |
| B<br>O<br>L<br>T<br>I<br>N<br>G                    | BOLTS PER FLANGE  |                    | 4    | 4                                  | 4    | 4     | 8    | 8    | 8    | 12    | 12   | 16    | 16    | 20                       | 20    | 24    | 24    | 24    |      |
|  | BOLT CIRCLE DIAMETER  |                    | 2.62 | 3.25                               | 3.5  | 4.5   | 5    | 6.62 | 7.88 | 10.62 | 13   | 15.25 | 17.75 | 20.25                    | 22.5  | 24.75 | 27    | 32    |      |
|  | DIAMETER OF BOLT  |                    | 1/2  | 5/8                                | 5/8  | 3/4   | 5/8  | 3/4  | 3/4  | 3/4   | 7/8  | 1     | 1 1/8 | 1 1/8                    | 1 1/4 | 1 1/4 | 1 1/4 | 1 1/2 |      |
|  | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5                         | RF                 | 2.5  | 3                                  | 3    | 3.5   | 3.5  | 4.25 | 4.5  | 4.75  | 5.5  | 6.25  | 6.75  | 7                        | 7.5   | 7.75  | 8     | 9     |      |
|  |   | RJ                 | 3    | 3.5                                | 3.5  | 4     | 4    | 4.75 | 5    | 5.5   | 6    | 6.75  | 7.25  | 7.5                      | 8     | 8.25  | 8.75  | 10    |      |

# CLASS 600 FLANGE DATA

- DIMENSIONS INCLUDE 0.25" RAISED FACE ON FLANGES (except lap-joint)
- DIMENSIONS INCLUDE 0.06" GAP FOR WELDING - REFER TO CHART 2.2


TABLE F-3

| NOMINAL PIPE SIZE: NPS   |   |                    | 1/2                                      | 3/4  | 1    | 1 1/2 | 2    | 3    | 4     | 6    | 8     | 10    | 12    | 14    | 16    | 18    | 20    | 24    |    |
|--------------------------|---|--------------------|--|------|------|-------|------|------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|----|
| OUTSIDE DIAMETER         |   |                    | 3.75                                     | 4.62 | 4.88 | 6.12  | 6.5  | 8.25 | 10.75 | 14   | 16.5  | 20    | 22    | 23.75 | 27    | 29.25 | 32    | 37    |    |
| FLANGE<br>TYPE           | <br>END OF<br>PIPE TO<br>FACE OF<br>FLANGE<br>or LAP<br>JOINT<br>STUB<br>END • | WELD-NECK          | 2.31                                     | 2.5  | 2.69 | 3     | 3.12 | 3.5  | 4.25  | 4.88 | 5.5   | 6.25  | 6.38  | 6.75  | 7.25  | 7.5   | 7.75  | 8.25  |    |
|                          |   | SLIP-ON            | Wall thickness of pipe + 0.06-inch       |      |      |       |      |      |       |      |       |       |       |       |       |       |       |       |    |
|                          |   | SOCKET ••          | 0.81                                     | 0.88 | 0.88 | 0.94  | 1.06 | 1.31 |       |      |       |       |       |       |       |       |       |       |    |
|                          |   | THREADED           | 0.38                                     | 0.31 | 0.31 | 0.44  | 0.69 | 0.50 | 0.62  | 0.88 | 0.94  | 0.94  | 1     |       |       |       |       |       |    |
|                          |   | L-J<br>STUB<br>END | ANSI                                     | 3    | 3    | 4     | 4    | 6    | 6     | 6    | 8     | 8     | 10    | 10    | 12    | 12    | 12    | 12    | 12 |
|                          |   |                    | MSS                                      | 2    | 2    | 2     | 2    | 2.5  | 2.5   | 3    | 3.5   | 4     | 5     | 6     | 6     | 6     | 6     | 6     | 6  |
| BORE: WELD-NECK & SOCKET |   |                    | Order to match Internal Diameter of pipe |      |      |       |      |      |       |      |       |       |       |       |       |       |       |       |    |
| BOLTING                  | BOLTS PER FLANGE  |                    | 4  | 4    | 4    | 4     | 8    | 8    | 8     | 12   | 12    | 16    | 20    | 20    | 20    | 20    | 24    | 24    |    |
|                          | BOLT CIRCLE DIAMETER  |                    | 2.62                                     | 3.25 | 3.5  | 4.5   | 5    | 6.62 | 8.5   | 11.5 | 13.75 | 17    | 19.25 | 20.75 | 23.75 | 25.75 | 28.5  | 33    |    |
|                          | DIAMETER OF BOLT  |                    | 1/2                                      | 5/8  | 5/8  | 3/4   | 5/8  | 3/4  | 7/8   | 1    | 1 1/8 | 1 1/4 | 1 1/4 | 1 3/8 | 1 1/2 | 1 5/8 | 1 5/8 | 1 7/8 |    |
|                          | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5   | RF                 | 3  | 3.5  | 3.5  | 4.25  | 4.25 | 5    | 5.75  | 6.75 | 7.5   | 8.5   | 8.75  | 9.25  | 10    | 10.75 | 11.25 | 13    |    |
|                          |   | RJ                 | 3  | 3.5  | 3.5  | 4.25  | 4.25 | 5    | 5.75  | 6.75 | 7.75  | 8.5   | 8.75  | 9.25  | 10    | 10.75 | 11.5  | 13.25 |    |

# CLASS 900 FLANGE DATA

- DIMENSIONS INCLUDE 0.25" RAISED FACE ON FLANGES (except lap-joint)

TABLE F-4


| NOMINAL PIPE SIZE: NPS |   |                    | 1/2                                      | 3/4  | 1    | 1 1/2 | 2    | 3    | 4    | 6    | 8    | 10   | 12   | 14    | 16    | 18   | 20    | 24    |
|------------------------|---|--------------------|--|------|------|-------|------|------|------|------|------|------|------|-------|-------|------|-------|-------|
| OUTSIDE DIAMETER       |   |                    | 4.75                                     | 5.12 | 5.88 | 7     | 8.5  | 9.5  | 11.5 | 15   | 18.5 | 21.5 | 24   | 25.25 | 27.75 | 31   | 33.75 | 41    |
| FLANGE<br>TYPE         | <br>END OF PIPE TO<br>FACE OF FLANGE<br>or LAP JOINT<br>STUB END • | WELD-NECK          | 2.62                                     | 3    | 3.12 | 3.5   | 4.25 | 4.25 | 4.75 | 5.75 | 6.62 | 7.5  | 8.12 | 8.62  | 8.75  | 9.25 | 10    | 11.75 |
|                        |   | SLIP-ON            | Wall thickness of pipe + 0.06-inch       |      |      |       |      |      |      |      |      |      |      |       |       |      |       |       |
|                        |   | SOCKET             | Not available in this class              |      |      |       |      |      |      |      |      |      |      |       |       |      |       |       |
|                        |   | THREADED           | 0.62                                     | 0.69 | 0.69 | 0.81  | 1.06 | 0.50 | 0.62 | 0.88 | 0.94 | 1    | 1    |       |       |      |       |       |
|                        |   | L-J<br>STUB<br>END | ANSI                                     | 3    | 3    | 4     | 4    | 6    | 6    | 6    | 8    | 8    | 10   | 10    | 12    | 12   | 12    | 12    |
|                        |   |                    | MSS                                      | 2    | 2    | 2     | 2    | 2.5  | 2.5  | 3    | 3.5  | 4    | 5    | 6     | 6     | 6    | 6     | 6     |
| BORE: WELD-NECK        |   |                    | Order to match Internal Diameter of pipe |      |      |       |      |      |      |      |      |      |      |       |       |      |       |       |

|         |   |    |      |     |     |      |      |      |       |       |       |       |       |       |       |       |       |       |
|---------|---|----|------|-----|-----|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| BOLTING | BOLTS PER FLANGE  |    | 4    | 4   | 4   | 4    | 8    | 8    | 8     | 12    | 12    | 16    | 20    | 20    | 20    | 20    | 20    | 20    |
|         | BOLT CIRCLE DIAMETER                                    |    | 3.25 | 3.5 | 4   | 4.88 | 6.5  | 7.5  | 9.25  | 12.5  | 15.5  | 18.5  | 21    | 22    | 24.25 | 27    | 29.5  | 35.5  |
|         | DIAMETER OF BOLT  |    | 3/4  | 3/4 | 7/8 | 1    | 7/8  | 7/8  | 1 1/8 | 1 1/8 | 1 3/8 | 1 3/8 | 1 3/8 | 1 1/2 | 1 5/8 | 1 7/8 | 2     | 2 1/2 |
|         | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5 | RF | 4.25 | 4.5 | 5   | 5.5  | 5.75 | 5.75 | 6.75  | 7.5   | 8.75  | 9.25  | 10    | 10.75 | 11.25 | 12.75 | 13.75 | 17.25 |
|         |   | RJ | 4.25 | 4.5 | 5   | 5.5  | 5.75 | 5.75 | 6.75  | 7.75  | 8.75  | 9.25  | 10    | 11    | 11.5  | 13.25 | 14.25 | 18    |

# CLASS 1500 FLANGE DATA

- DIMENSIONS INCLUDE 0.25" RAISED FACE ON FLANGES (except lap-joint)
- DIMENSIONS INCLUDE 0.06" GAP FOR WELDING - REFER TO CHART 2.2

# TABLE F-5


| NOMINAL PIPE SIZE: NPS                             |   |                    | 1/2                                      | 3/4  | 1    | 1 1/2 | 2    | 3    | 4     | 6    | 8    | 10    | 12    | 14   | 16   | 18    | 20    | 24    |    |
|--|---|--------------------|--|------|------|-------|------|------|-------|------|------|-------|-------|------|------|-------|-------|-------|----|
| OUTSIDE DIAMETER                                   |   |                    | 4.75                                     | 5.12 | 5.88 | 7     | 8.5  | 10.5 | 12.25 | 15.5 | 19   | 23    | 26.5  | 29.5 | 32.5 | 36    | 38.75 | 46    |    |
| F<br>L<br>A<br>N<br>G<br>E<br><br>T<br>Y<br>P<br>E | <br>END OF<br>PIPE TO<br>FACE OF<br>FLANGE<br>or LAP<br>JOINT<br>STUB<br>END • | WELD-NECK          | 2.62                                     | 3    | 3.12 | 3.5   | 4.25 | 4.88 | 5.12  | 7    | 8.62 | 10.25 | 11.38 | 12   | 12.5 | 13.12 | 14.25 | 16.25 |    |
|  |   | SLIP-ON            | Wall thickness of pipe + 0.06-inch       |      |      |       |      |      |       |      |      |       |       |      |      |       |       |       |    |
|  |   | SOCKET ••          | 1.19                                     | 1.25 | 1.44 | 1.44  | 1.88 |      |       |      |      |       |       |      |      |       |       |       |    |
|  |   | THREADED           | 0.38                                     | 0.31 | 0.31 | 0.38  | 0.62 | 0.50 | 0.62  | 0.88 | 0.94 | 0.94  | 1     |      |      |       |       |       |    |
|  |   | L-J<br>STUB<br>END | ANSI                                     | 3    | 3    | 4     | 4    | 6    | 6     | 6    | 8    | 8     | 10    | 10   | 12   | 12    | 12    | 12    | 12 |
|  |   |                    | MSS                                      | 2    | 2    | 2     | 2    | 2.5  | 2.5   | 3    | 3.5  | 4     | 5     | 6    | 6    | 6     | 6     | 6     | 6  |
| BORE: WELD-NECK & SOCKET                           |   |                    | Order to match Internal Diameter of pipe |      |      |       |      |      |       |      |      |       |       |      |      |       |       |       |    |

|                                 |   |    |      |     |     |      |      |       |       |       |       |       |       |       |       |       |       |       |
|---------------------------------|---|----|------|-----|-----|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| B<br>O<br>L<br>T<br>I<br>N<br>G | BOLTS PER FLANGE  |    | 4    | 4   | 4   | 4    | 8    | 8     | 8     | 12    | 12    | 12    | 16    | 16    | 16    | 16    | 16    | 16    |
|                                 | BOLT CIRCLE DIAMETER                                    |    | 3.25 | 3.5 | 4   | 4.88 | 6.5  | 8     | 9.5   | 12.5  | 15.5  | 19    | 22.5  | 25    | 27.75 | 30.5  | 32.75 | 39    |
|                                 | DIAMETER OF BOLT  |    | 3/4  | 3/4 | 7/8 | 1    | 7/8  | 1 1/8 | 1 1/4 | 1 3/8 | 1 5/8 | 1 7/8 | 2     | 2 1/4 | 2 1/2 | 2 3/4 | 3     | 3 1/2 |
|                                 | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5 | RF | 4.25 | 4.5 | 5   | 5.5  | 5.75 | 7     | 7.75  | 10.25 | 11.5  | 13.25 | 14.75 | 16    | 17.5  | 19.5  | 21.25 | 24.25 |
|                                 |   | RJ | 4.25 | 4.5 | 5   | 5.5  | 5.75 | 7     | 7.75  | 10.5  | 12.75 | 13.5  | 15.25 | 16.75 | 18.5  | 20.75 | 22.25 | 25.5  |

# CLASS 2500 FLANGE DATA

- DIMENSIONS INCLUDE 0.25" RAISED FACE ON FLANGES (except lap-joint)

# TABLE F-6

| NOMINAL PIPE SIZE: NPS                             |   |                    | 1/2                                      | 3/4                                | 1    | 1 1/2 | 2    | 3     | 4     | 6    | 8     | 10    | 12    | 14   | 16 | 18 | 20 | 24 |
|--|---|--------------------|--|------------------------------------|------|-------|------|-------|-------|------|-------|-------|-------|------|----|----|----|----|
| OUTSIDE DIAMETER                                   |   |                    | 5.25                                     | 5.5                                | 6.25 | 8     | 9.25 | 12    | 14    | 19   | 21.75 | 26.5  | 30    |      |    |    |    |    |
| F<br>L<br>A<br>N<br>G<br>E<br><br>T<br>Y<br>P<br>E | <br>END OF<br>PIPE TO<br>FACE OF<br>FLANGE<br>or LAP<br>JOINT<br>STUB<br>END • | WELD-NECK          |  | 3.12                               | 3.38 | 3.75  | 4.62 | 5.25  | 6.88  | 7.75 | 11    | 12.75 | 16.75 | 18.5 |    |    |    |    |
|  |   | SLIP-ON            |  | Wall thickness of pipe + 0.06-inch |      |       |      |       |       |      |       |       |       |      |    |    |    |    |
|  |   | SOCKET             |  | Not available in this class        |      |       |      |       |       |      |       |       |       |      |    |    |    |    |
|  |   | THREADED           |  | 0.31                               | 0.44 | 0.31  | 0.69 | 0.88  | 0.5   | 0.62 | 0.88  | 0.94  | 1.06  | 1    |    |    |    |    |
|  |   | L-J<br>STUB<br>END | ANSI                                     | 3                                  | 3    | 4     | 4    | 6     | 6     | 6    | 8     | 8     | 10    | 10   |    |    |    |    |
|  |   |                    | MSS                                      | 2                                  | 2    | 2     | 2    | 2.5   | 2.5   | 3    | 3.5   | 4     | 5     | 6    |    |    |    |    |
| BORE: WELD-NECK                                    |   |                    | Order to match Internal Diameter of pipe |                                    |      |       |      |       |       |      |       |       |       |      |    |    |    |    |
| B<br>O<br>L<br>T<br>I<br>N<br>G                    | BOLTS PER FLANGE  |                    | 4  | 4                                  | 4    | 4     | 8    | 8     | 8     | 8    | 12    | 12    | 12    |      |    |    |    |    |
|  | BOLT CIRCLE DIAMETER  |                    | 3.5                                      | 3.75                               | 4.25 | 5.75  | 6.75 | 9     | 10.75 | 14.5 | 17.25 | 21.25 | 24.38 |      |    |    |    |    |
|  | DIAMETER OF BOLT  |                    | 3/4                                      | 3/4                                | 7/8  | 1 1/8 | 1    | 1 1/4 | 1 1/2 | 2    | 2     | 2 1/2 | 2 3/4 |      |    |    |    |    |
|  | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5   | RF                 | 4.75                                     | 5                                  | 5.5  | 6.75  | 7    | 8.75  | 10    | 13.5 | 15    | 19.25 | 21.25 |      |    |    |    |    |
|  |   | RJ                 | 4.75                                     | 5                                  | 5.5  | 6.75  | 7    | 9     | 10.25 | 14   | 15.5  | 20    | 22    |      |    |    |    |    |

# RING-JOINT GASKET DATA

TABLE F-7

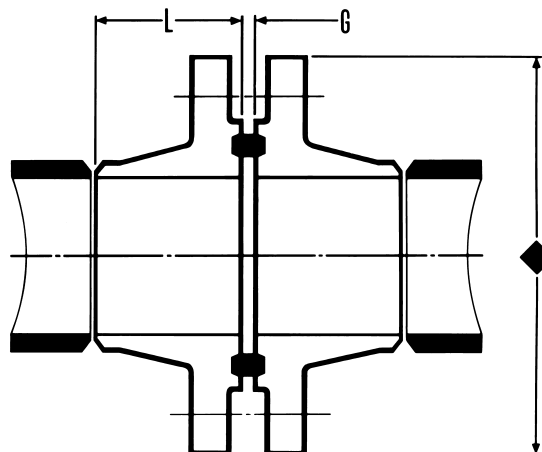
DIMENSIONS IN INCHES

## DATA FOR WELDING-NECK FLANGES

L = LENGTH THRU HUB OF WELDING-NECK FLANGE WITH RING JOINT

G = GAP BETWEEN FLANGE FACES WITH RING IN COMPRESSION

◆ FOR OUTSIDE DIAMETERS OF FLANGES AND BOLTING REFER TO TABLES F-1 THRU F-6



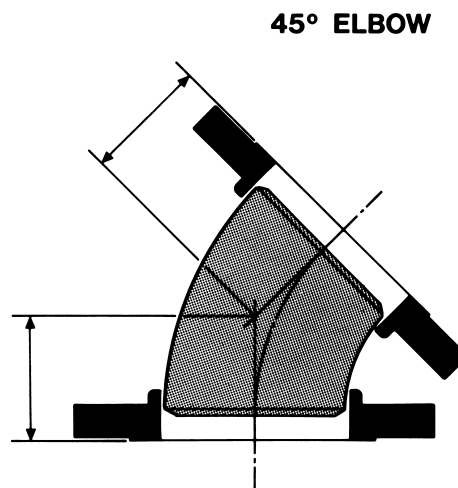
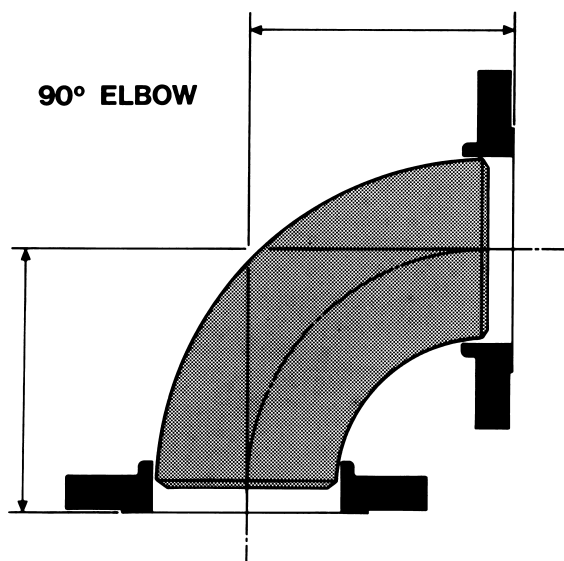
## FLANGE CLASSES

| NPS   | 150  |      |         | 300  |      |         | 600  |      |         | 900   |      |         | 1500  |      |         | 2500  |      |         |
|-------|------|------|---------|------|------|---------|------|------|---------|-------|------|---------|-------|------|---------|-------|------|---------|
|       | L    | G    | RING No | L    | G    | RING No | L    | G    | RING No | L     | G    | RING No | L     | G    | RING No | L     | G    | RING No |
| 1/2   | -    | -    | -       | 2.31 | 0.12 | R 11    | 2.31 | 0.12 | R 11    | 2.62  | 0.16 | R 12    | 2.62  | 0.16 | R 12    | 3.12  | 0.16 | R 13    |
| 3/4   | -    | -    | -       | 2.50 | 0.16 | R 13    | 2.50 | 0.16 | R 13    | 3     | 0.16 | R 14    | 3     | 0.16 | R 14    | 3.38  | 0.16 | R 16    |
| 1     | 2.44 | 0.16 | R 15    | 2.69 | 0.16 | R 16    | 2.69 | 0.16 | R 16    | 3.12  | 0.16 | R 16    | 3.12  | 0.16 | R 16    | 3.75  | 0.16 | R 18    |
| 1 1/2 | 2.69 | 0.16 | R 19    | 2.94 | 0.16 | R 20    | 3    | 0.16 | R 20    | 3.50  | 0.16 | R 20    | 3.50  | 0.16 | R 20    | 4.69  | 0.12 | R 23    |
| 2     | 2.75 | 0.16 | R 22    | 3.06 | 0.22 | R 23    | 3.19 | 0.19 | R 23    | 4.31  | 0.12 | R 24    | 4.31  | 0.12 | R 24    | 5.31  | 0.12 | R 26    |
| 3     | 3    | 0.16 | R 29    | 3.44 | 0.22 | R 31    | 3.56 | 0.19 | R 31    | 4.13  | 0.16 | R 31    | 4.94  | 0.12 | R 35    | 7     | 0.12 | R 32    |
| 4     | 3.25 | 0.16 | R 36    | 3.69 | 0.22 | R 37    | 4.31 | 0.19 | R 37    | 4.81  | 0.16 | R 37    | 5.19  | 0.12 | R 39    | 7.94  | 0.16 | R 38    |
| 6     | 3.75 | 0.16 | R 43    | 4.19 | 0.22 | R 45    | 4.94 | 0.19 | R 45    | 5.81  | 0.16 | R 45    | 7.12  | 0.12 | R 46    | 11.25 | 0.16 | R 47    |
| 8     | 4.25 | 0.16 | R 48    | 4.69 | 0.22 | R 49    | 5.56 | 0.19 | R 49    | 6.69  | 0.16 | R 49    | 8.81  | 0.16 | R 50    | 13.06 | 0.19 | R 51    |
| 10    | 4.25 | 0.16 | R 52    | 4.94 | 0.22 | R 53    | 6.31 | 0.19 | R 53    | 7.56  | 0.16 | R 53    | 10.44 | 0.16 | R 54    | 17.19 | 0.25 | R 55    |
| 12    | 4.75 | 0.16 | R 56    | 5.44 | 0.22 | R 57    | 6.44 | 0.19 | R 57    | 8.19  | 0.16 | R 57    | 11.69 | 0.19 | R 58    | 18.94 | 0.31 | R 60    |
| 14    | 5.25 | 0.12 | R 59    | 5.94 | 0.22 | R 61    | 6.81 | 0.19 | R 61    | 8.81  | 0.16 | R 62    | 12.38 | 0.22 | R 63    |       |      |         |
| 16    | 5.25 | 0.12 | R 64    | 6.06 | 0.22 | R 65    | 7.31 | 0.19 | R 65    | 8.94  | 0.16 | R 66    | 12.94 | 0.31 | R 67    |       |      |         |
| 18    | 5.75 | 0.12 | R 68    | 6.56 | 0.22 | R 69    | 7.56 | 0.19 | R 69    | 9.50  | 0.19 | R 70    | 13.56 | 0.31 | R 71    |       |      |         |
| 20    | 5.94 | 0.12 | R 72    | 6.75 | 0.22 | R 73    | 7.88 | 0.19 | R 73    | 10.25 | 0.19 | R 74    | 14.69 | 0.38 | R 75    |       |      |         |
| 24    | 6.25 | 0.12 | R 76    | 7.06 | 0.25 | R 77    | 8.44 | 0.22 | R 77    | 12.12 | 0.22 | R 78    | 16.81 | 0.44 | R 79    |       |      |         |

# SLIP-ON FLANGES ON BUTT-WELDING ELBOWS

**TABLE F-8**

FOR USE ON BUTT-WELDING ELBOWS AS PERMITTED BY THE PIPING SPECIFICATION FOR THE PROJECT



LR = LONG RADIUS

SR = SHORT RADIUS

\* INDICATES NUMBER OF FLANGES WITHOUT INTERFERENCE

| NPS | CLASS 150 FLANGES |   |       |   |       |   | CLASS 300 FLANGES |   |       |   |       |   |
|-----|-------------------|---|-------|---|-------|---|-------------------|---|-------|---|-------|---|
|     | 90 LR             | * | 90 SR | * | 45 LR | * | 90 LR             | * | 90 SR | * | 45 LR | * |
| 2   | 3.50              | 1 | 2.69  | 1 | 1.88  | 1 | 3.81              | 1 | 3.00  | 1 | 2.19  | 1 |
| 3   | 5.12              | 2 | 3.81  | 1 | 2.62  | 1 | 5.62              | 1 | 4.31  | 1 | 3.12  | 1 |
| 4   | 6.62              | 2 | 4.88  | 1 | 3.12  | 1 | 7.19              | 2 | 5.44  | 1 | 3.69  | 1 |
| 6   | 9.56              | 2 | 6.88  | 1 | 4.31  | 2 | 10.06             | 2 | 7.38  | 1 | 4.81  | 2 |
| 8   | 12.56             | 2 | 8.94  | 2 | 5.56  | 2 | 13.25             | 2 | 9.62  | 2 | 6.25  | 2 |
| 10  | 15.62             | 2 | 10.88 | 2 | 6.88  | 2 | 16.06             | 2 | 11.56 | 2 | 7.31  | 2 |
| 12  | 18.62             | 2 | 13.06 | 2 | 8.12  | 2 | 19.19             | 2 | 13.75 | 2 | 8.69  | 2 |
| 14  | 21.62             | 2 | 14.81 | 2 | 9.38  | 2 | 22.00             | 2 | 15.56 | 2 | 9.75  | 2 |
| 16  | 24.62             | 2 | 17.00 | 2 | 10.62 | 2 | 24.88             | 2 | 17.75 | 2 | 10.88 | 2 |
| 18  | 27.62             | 2 | 19.06 | 2 | 11.88 | 2 | 28.00             | 2 | 19.88 | 2 | 12.25 | 2 |
| 20  | 30.62             | 2 | 21.00 | 2 | 13.12 | 2 | 31.25             | 2 | 21.88 | 2 | 13.75 | 2 |
| 24  | 36.62             | 2 | 25.38 | 2 | 15.62 | 2 | 37.44             | 2 | 26.31 | 2 | 16.44 | 2 |

DIMENSIONS IN INCHES

# **PRESSURE / TEMPERATURE RATINGS FOR CARBON STEEL FLANGES**

**TABLE F-9**

Maximum Ratings for flanges conforming to ANSI Standard B16.5 dimensions and material specification ASTM A-105

| <div> <div>TEMPERATURE</div> <div>FAHRENHEIT</div> </div> | GAGE WORKING PRESSURE IN psi FOR FLANGE CLASSES 150 - 2500 |     |     |      |      |      |      |
|---|--|-----|-----|------|------|------|------|
|   | F L A N G E C L A S S E S                                  |     |     |      |      |      |      |
|   | 150  | 300 | 400 | 600  | 900  | 1500 | 2500 |
| -20 to 100  | 285  | 740 | 990 | 1480 | 2220 | 3705 | 6170 |
| 200   | 260  | 675 | 900 | 1350 | 2025 | 3375 | 5625 |
| 300   | 230  | 655 | 875 | 1315 | 1970 | 3280 | 5470 |
| 400   | 200  | 635 | 845 | 1270 | 1900 | 3170 | 5280 |
| 500   | 170  | 600 | 800 | 1200 | 1795 | 2995 | 4990 |
| 600   | 140  | 550 | 730 | 1095 | 1640 | 2735 | 4560 |
| 650   | 125  | 535 | 715 | 1075 | 1610 | 2685 | 4475 |
| 700   | 110  | 535 | 710 | 1065 | 1600 | 2665 | 4440 |
| 750   | 95   | 505 | 670 | 1010 | 1510 | 2520 | 4200 |
| 800   | 80   | 410 | 550 | 825  | 1235 | 2060 | 3430 |
| 850   | 65   | 270 | 355 | 535  | 805  | 1340 | 2230 |
| 900   | 50   | 170 | 230 | 345  | 515  | 860  | 1430 |
| 950   | 35   | 105 | 140 | 205  | 310  | 515  | 860  |
| 1000  | 20   | 50  | 70  | 105  | 155  | 260  | 430  |

Standard ANSI B16.5 does not recommend using flanges manufactured from carbon steels made to ASTM specification A-105 at temperatures in excess of 1000F (538C) at any time, or their prolonged usage at temperatures over 800F (427C). [ASTM A-105 carbon steel is included in material group 1.1. of ANSI B16.5.]



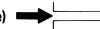
## **THERMAL GRADIENTS, THERMAL CYCLING and EXTERNAL LOADS**

The suitability of slip-on, socket-welding and threaded flange attachments at 540F (282C) and -50F (-46C) is discussed in ANSI B16.5, which also makes recommendations to prevent leakage from Class 150 flanged joints at 400F (204C), and other classes at higher temperatures, if the above operating conditions are anticipated, and expected to be severe.

Ratings are for non-shock conditions. Values in this table do not prevail over limitations imposed by codes, standards, regulations or other obligations which may pertain to projects.

# FLOW RESISTANCE OF FITTINGS & VALVES

## TABLE F-10

| NOMINAL PIPE SIZE (IN.)  |   | 1/2                                 | 3/4 | 1   | 1 1/2 | 2   | 3   | 4   | 6    | 8    | 10   | 12   | 14   | 16   | 18   | 20   | 24   |      |     |
|--|---|-------------------------------------|-----|-----|-------|-----|-----|-----|------|------|------|------|------|------|------|------|------|------|-----|
| FITTINGS & CONNECTIONS   | 90° LONG-RADIUS ELBOW   |                                     | 2.3 | 2.8 | 3.2   | 4.9 | 2.3 | 3.5 | 4.5  | 6.8  | 9.0  | 11   | 13   | 15   | 17   | 19   | 21   | 25   |     |
|  | 90° SHORT-RADIUS ELBOW  |                                     |     |     |       |     | 6.7 | 9.8 | 13   | 19   | 25   | 21   | 37   | 38   | 44   | 49   | 55   | 66   |     |
|  | 45° ELBOW (LONG RADIUS)   |                                     | 0.4 | 0.6 | 0.8   | 1.3 | 1.1 | 1.8 | 2.5  | 4.0  | 5.5  | 7.4  | 9.5  | 10   | 12   | 14   | 16   | 20   |     |
|  | RETURN, LONG-RADIUS   |                                     | 2.3 | 2.8 | 3.5   | 4.9 | 5.1 | 7.5 | 9.8  | 15   | 19   | 24   | 29   | 32   | 36   | 41   | 45   | 55   |     |
|  | RETURN, SHORT-RADIUS  |                                     |     |     |       |     | 13  | 20  | 25   | 39   | 50   | 63   | 75   | 78   | 89   | 100  | 110  | 130  |     |
|  | 90° MITERS<br>(90° Change in direction)                         | 2-PIECE                             |     |     |       |     |     |     |      | 21   | 34   | 47   | 63   | 80   | 88   | 110  | 120  | 140  | 170 |
|  |   | 3-PIECE                             |     |     |       |     |     |     |      | 9.3  | 14   | 18   | 23   | 27   | 30   | 34   | 38   | 43   | 51  |
|  |   | 4-PIECE                             |     |     |       |     |     |     |      | 8.5  | 13   | 17   | 21   | 25   | 27   | 31   | 35   | 39   | 47  |
|  |   | 5-PIECE                             |     |     |       |     |     |     |      | 6.3  | 9.5  | 13   | 16   | 19   | 20   | 23   | 26   | 29   | 35  |
|  | REDUCER and SWAGE<br><small>Note (3)</small>                    | One listed NPS reduction            |     |     | 1.1   | 3.1 | 2.8 | 11  | 9.0  | 22   | 21   | 48   | 79   | 130  | 270  | 240  | 330  | 390  | 270 |
|  |   | One listed NPS increase             |     | 1.1 | 2.2   | 2.9 | 3.3 | 9.4 | 14   | 23   | 33   | 45   | 54   | 28   | 46   | 47   | 43   | 100  |     |
|  | VENTURI SWAGE – One listed NPS increase <small>Note (3)</small> |                                     |     |     |       |     |     | 2.7 | 3.0  | 4.7  | 6.2  | 8.3  | 12   | 21   | 17   | 21   | 25   | 49   |     |
| STRAIGHT TEE   | Thru run  |                                     | 1.0 | 1.5 | 2.1   | 3.7 | 1.6 | 2.2 | 2.6  | 3.6  | 4.2  | 5.0  | 5.9  | 6.3  | 6.9  | 7.8  | 8.4  | 9.1  |     |
|  | Thru branch and run   |                                     | 2.7 | 3.3 | 4.1   | 6.1 | 6.6 | 9.7 | 13   | 18   | 23   | 29   | 35   | 36   | 41   | 45   | 49   | 59   |     |
| UNION and COUPLING (Screwed, pipe-to-pipe)   |   |                                     | 0.2 | 0.2 | 0.2   | 0.3 |     |     |      |      |      |      |      |      |      |      |      |      |     |
| REDUCING FLANGE<br><small>Note (3)</small>   | One listed NPS reduction  |                                     |     | 0.1 | 0.2   | 0.2 | 0.6 | 0.7 | 1.4  | 1.6  | 3.1  | 4.4  | 5.8  | 6.2  | 7.1  | 8.4  | 9.4  | 12   |     |
|  | One listed NPS increase   |                                     | 0.2 | 0.2 | 0.8   | 0.6 | 2.4 | 2.4 | 5.8  | 5.3  | 5.6  | 4.9  | 2.1  | 4.3  | 4.1  | 4.1  | 11   |      |     |
| BELLMOUTH OUTLET (Vessel-to-line)         |   |                                     | 0.1 | 0.1 | 0.1   | 0.2 | 0.4 | 0.7 | 0.9  | 1.4  | 2.1  | 2.8  | 3.6  | 3.9  | 4.6  | 5.4  | 6.0  | 7.5  |     |
| INLET, Flush with Wall (Line-to-vessel)   |   |                                     | 1.1 | 1.6 | 2.3   | 4.1 | 8.2 | 14  | 19   | 30   | 42   | 56   | 71   | 78   | 93   | 108  | 120  | 150  |     |
| OUTLET, Flush with Wall (Vessel-to-line)  |   |                                     | 0.6 | 0.8 | 1.2   | 2.0 | 4.1 | 6.8 | 9.3  | 15   | 21   | 28   | 36   | 39   | 46   | 54   | 60   | 75   |     |
| OPEN VALVES  | GATE VALVE  |                                     | 0.4 | 0.4 | 0.5   | 0.8 | 2.2 | 2.8 | 3.0  | 3.3  | 3.1  | 3.3  | 3.1  | 3.1  | 3.1  | 3.3  | 3.0  | 2.7  |     |
|  | GLOBE VALVE   | Regular Disc                        |     |     |       |     | 71  | 97  | 120  | 180  | 240  | 310  | 390  |      |      |      |      |      |     |
|  |   | Composition Disc                    | 15  | 16  | 20    | 29  | 70  | 94  | 120  | 170  | 230  | 300  | 380  |      |      |      |      |      |     |
|  |   | Plug-type Disc                      |     |     |       |     | 100 | 140 | 170  | 250  | 330  | 440  | 560  |      |      |      |      |      |     |
|  | CHECK VALVE   | Swing                               | 5.2 | 5.7 | 6.7   | 10  | 16  | 27  | 37   | 59   | 83   | 110  | 140  | 160  | 190  |      |      |      |     |
|  |   | Ball                                | 170 | 190 | 220   | 320 | 530 | 880 | 1200 | 1900 | 2700 | 3600 | 4600 | 5100 | 6000 | 7000 | 7800 | 9800 |     |
|  |   | Tilting-disc                        |     |     |       |     | 82  | 140 | 190  | 300  | 420  | 560  | 710  | 780  | 930  | 1100 | 1200 | 1500 |     |
|  | ROTARY-BALL VALVE   | Regular Pattern, (Walworth Alloyco) | 4.0 | 3.9 | 1.2   | 3.3 | 5.6 | 4.0 | 15   | 10   | 35   | 56   | 48   |      |      |      |      |      |     |
|  |   | Eccentric Pattern (DeZurik)         | 1.6 | 1.7 | 2.2   | 3.9 | 3.7 | 5.7 | 8.0  | 15   | 21   | 28   | 40   | 38   | 45   | 49   | 47   | 57   |     |
|  | BUTTERFLY VALVE (Walworth 'Pinnacle' Valve)                     |                                     |     |     |       |     |     | 8.8 | 6.1  | 5.5  | 8.3  | 8.4  | 11   | 16   |      |      |      |      |     |
| PLUG VALVE 1"-12": Regular pattern<br>14"-24": Venturi pattern (W-K-M 'ACF')   |   |                                     |     |     | 1.7   | 4.1 | 5.5 | 8.2 | 14   | 56   | 96   | 100  | 140  | 88   | 130  | 120  | 160  | 170  |     |

### NOTES

- [1] Hydraulic resistances are for turbulent flow and are given as lengths of SCH 40 pipe having the same resistance. For pipe with a thicker wall use the resistance value for SCH 40 pipe having the closest internal diameter.
- [2] Numbers in italics are resistances for threaded valves and fittings. Upright numbers relate to flanged valves and butt-welding fittings.
- [3] For reducing and increasing fittings, flow resistance is based on the nominal pipe size at the inflow end.
- [4] Tabulated flow resistances are approximate and selected from several sources not all giving comparable values. These sources include the Hydraulic Institute's "Pipe Friction Manual", the Crane Company's Technical Paper 410", the "Reactor Handbook" (Interscience), the "Chemical Engineer's Handbook", (McGraw-Hill), "Cameron Hydraulic Data" (Ingersoll-Rand), and manufacturers' catalogs.

#### FRACTIONAL EQUIVALENTS

|      |      |      |      |      |      |      |      |      |      |       |      |       |      |       |
|------|------|------|------|------|------|------|------|------|------|-------|------|-------|------|-------|
| 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.38 | 0.44 | 0.50 | 0.56 | 0.62 | 0.69  | 0.75 | 0.81  | 0.88 | 0.94  |
| 1/16 | 1/8  | 3/16 | 1/4  | 5/16 | 3/8  | 7/16 | 1/2  | 9/16 | 5/8  | 11/16 | 3/4  | 13/16 | 7/8  | 15/16 |

# FLOW OF WATER THRU SCH 40 PIPE

# TABLE F-11

| FLOW RATE |           | PRESSURE DROP (PSI) PER 100 ft SCH 40 PIPE |          |             |          |             |          |             |          |             |          |             |          |
|-----------|-----------|--|----------|-------------|----------|-------------|----------|-------------|----------|-------------|----------|-------------|----------|
| GPM       | Cu.ft/sec | v<br>Ft/Sec                                | p<br>psi | v<br>Ft/Sec | p<br>psi | v<br>Ft/Sec | p<br>psi | v<br>Ft/Sec | p<br>psi | v<br>Ft/Sec | p<br>psi | v<br>Ft/Sec | p<br>psi |
| .1        | .00022    | 1/8"                                       |          | 1/4"        |          | 3/8"        |          | 1/2"        |          | 3/4"        |          | 1"          |          |
| .2        | .00045    | .56  | .677     | .62         | .548     | .50         | .255     | .42         | .136     | .30         | .050     | .36         | .071     |
| .3        | .00067    | 1.70                                       | 5.26     | .93         | 1.16     | .67         | .436     | .53         | .205     | .48         | .121     | .30         | .036     |
| .4        | .0089     | 2.26                                       | 9.00     | 1.24        | 1.98     | .84         | .656     | .63         | .290     | .50         | .136     | .30         | .036     |
| .5        | .00111    | 2.82                                       | 13.58    | 1.55        | 3.00     | 1.01        | .925     | .84         | .494     | .50         | .136     | .30         | .036     |
| .6        | .00134    | 3.38                                       | 19.12    | 1.85        | 4.22     | 1.34        | 1.58     | .84         | .494     | .50         | .136     | .30         | .036     |
| .8        | .00178    | 4.52                                       | 32.62    | 2.47        | 7.17     | 1.34        | 1.58     | .84         | .494     | .50         | .136     | .30         | .036     |
| 1         | .00223    | 1 1/2"                                     |          | 3.09        | 10.91    | 1.68        | 2.39     | 1.06        | .749     | .60         | .183     | .37         | .055     |
| 2         | .00446    | 1 1/2"                                     |          | 6.18        | 39.60    | 3.36        | 8.68     | 2.11        | 2.72     | 1.20        | .665     | .74         | .199     |
| 3         | .00668    | 1 1/2"                                     |          |             |          | 5.04        | 18.46    | 3.17        | 5.77     | 1.80        | 1.41     | 1.11        | .424     |
| 4         | .00891    | 1 1/2"                                     |          |             |          | 6.72        | 31.55    | 4.22        | 9.86     | 2.40        | 2.42     | 1.49        | .724     |
| 5         | .01114    | 1 1/2"                                     |          |             |          |             |          | 5.28        | 14.92    | 3.01        | 3.64     | 1.86        | 1.09     |
| 6         | .01337    | 1 1/2"                                     |          |             |          |             |          | 6.33        | 20.95    | 3.61        | 5.13     | 2.23        | 1.54     |
| 8         | .01782    | 1.26                                       | .308     | 2"          |          |             |          |             |          | 4.81        | 8.76     | 2.97        | 2.62     |
| 10        | .02228    | 1.58                                       | .466     | 2"          |          |             |          |             |          | 6.01        | 13.28    | 3.713       | 3.97     |
| 15        | .03342    | 2.36                                       | .992     | 1.43        | .285     | 2 1/2"      |          |             |          |             |          | 5.57        | 8.46     |
| 20        | .04456    | 3.15                                       | 1.69     | 1.91        | .486     | 2 1/2"      |          |             |          |             |          | 7.43        | 14.42    |
| 25        | .05570    | 3.94                                       | 2.54     | 2.39        | .736     | 2 1/2"      |          |             |          |             |          |             |          |
| 30        | .06684    | 4.73                                       | 3.60     | 2.37        | 1.03     | 2.01        | .424     | 3"          |          |             |          |             |          |
| 35        | .07798    | 5.51                                       | 4.79     | 3.35        | 1.37     | 2.35        | .566     | 3"          |          |             |          |             |          |
| 40        | .08912    | 6.30                                       | 6.14     | 3.82        | 1.76     | 2.68        | .724     | 3"          |          |             |          |             |          |
| 50        | .1114     | 7.88                                       | 9.31     | 4.78        | 2.67     | 3.35        | 1.10     | 2.17        | .371     | 3 1/2"      |          |             |          |
| 60        | .1337     | 9.45                                       | 13.08    | 5.74        | 3.75     | 4.02        | 1.54     | 2.61        | .520     | 3 1/2"      |          |             |          |
| 70        | .1560     |  |          | 6.70        | 4.99     | 4.70        | 2.05     | 3.04        | .693     | 2.27        | .335     | 4"          |          |
| 80        | .1782     |  |          | 7.65        | 6.40     | 5.37        | 2.63     | 3.47        | .890     | 2.59        | .430     | 4"          |          |
| 90        | .2005     |  |          | 8.60        | 7.96     | 6.04        | 3.28     | 3.91        | 1.10     | 2.92        | .535     | 4"          |          |
| 100       | .2228     |  |          | 9.56        | 9.69     | 6.71        | 3.98     | 4.34        | 1.34     | 3.24        | .650     | 2.52        | .346     |
| 125       | .2785     | 6"   |          |             |          | 8.38        | 6.03     | 5.43        | 2.01     | 4.05        | .984     | 3.15        | .523     |
| 150       | .3342     | 6"   |          |             |          | 10.1        | 8.46     | 6.52        | 2.86     | 4.87        | 1.38     | 3.78        | .734     |
| 175       | .3899     | 6"   |          |             |          | 11.7        | 11.3     | 7.60        | 3.81     | 5.68        | 1.84     | 4.41        | .978     |
| 200       | .4456     | 6"   |          |             |          | 13.4        | 14.4     | 8.69        | 4.89     | 6.49        | 2.36     | 5.04        | 1.25     |
| 225       | .5013     | 6"   |          |             |          |             |          | 9.77        | 6.09     | 7.30        | 2.94     | 5.67        | 1.56     |
| 250       | .5570     | 2.78                                       | .245     | 8"          |          |             |          | 10.9        | 7.41     | 8.11        | 3.58     | 6.30        | 1.90     |
| 275       | .6127     | 3.06                                       | .292     | 8"          |          |             |          | 11.9        | 8.84     | 8.92        | 4.27     | 6.93        | 2.27     |
| 300       | .6684     | 3.33                                       | .344     | 8"          |          |             |          | 13.0        | 10.4     | 9.73        | 5.02     | 7.56        | 2.67     |
| 350       | .7798     | 3.89                                       | .457     | 8"          |          |             |          | 15.2        | 13.8     | 11.4        | 6.87     | 8.82        | 3.55     |
| 400       | .8912     | 4.44                                       | .587     | 2.57        | .149     | 10"         |          |             |          | 13.0        | 8.58     | 10.1        | 4.56     |
| 450       | 1.003     | 5.00                                       | .731     | 2.89        | .185     | 10"         |          |             |          | 14.6        | 10.7     | 11.3        | 5.66     |
| 500       | 1.114     | 5.55                                       | .887     | 3.21        | .225     | 10"         |          |             |          | 16.2        | 13.0     | 12.6        | 6.89     |
| 550       | 1.225     | 6.11                                       | 1.07     | 3.53        | .270     | 10"         |          |             |          | 17.8        | 15.5     | 13.9        | 8.25     |
| 600       | 1.337     | 6.66                                       | 1.25     | 3.85        | .316     | 10"         |          |             |          | 19.5        | 18.2     | 15.1        | 9.68     |
| 650       | 1.449     | 7.22                                       | 1.45     | 4.17        | .367     | 2.65        | .118     |             |          |             |          | 16.4        | 11.2     |
| 700       | 1.560     | 7.78                                       | 1.66     | 4.49        | .420     | 2.85        | .135     | 12"         |          |             |          | 17.6        | 12.9     |
| 750       | 1.671     | 8.33                                       | 1.89     | 4.81        | .480     | 3.05        | .154     | 12"         |          |             |          | 18.9        | 14.7     |
| 800       | 1.782     | 8.89                                       | 2.13     | 5.13        | .540     | 3.26        | .173     | 12"         |          |             |          | 20.2        | 16.5     |
| 850       | 1.894     | 9.44                                       | 2.38     | 5.45        | .605     | 3.46        | .194     | 12"         |          |             |          | 21.4        | 18.5     |
| 900       | 2.005     | 10.0                                       | 2.66     | 5.77        | .627     | 3.66        | .216     | 2.58        | .090     |             |          | 22.7        | 20.6     |
| 950       | 2.117     | 10.6                                       | 2.93     | 6.09        | .744     | 3.87        | .238     | 2.72        | .099     | 14"         |          | 23.9        | 22.8     |
| 1000      | 2.228     | 11.1                                       | 3.23     | 6.41        | .817     | 4.07        | .262     | 2.87        | .109     | 14"         |          |             |          |
| 1100      | 2.451     | 12.2                                       | 3.85     | 7.06        | .975     | 4.48        | .313     | 3.15        | .130     | 14"         |          |             |          |
| 1200      | 2.674     | 13.3                                       | 4.53     | 7.70        | 1.15     | 4.88        | .368     | 3.44        | .153     | 2.85        | .096     |             |          |
| 1300      | 2.896     | 14.4                                       | 5.26     | 8.34        | 1.33     | 5.29        | .427     | 3.73        | .178     | 3.08        | .111     |             |          |
| 1400      | 3.119     | 15.6                                       | 6.01     | 8.98        | 1.53     | 5.70        | .490     | 4.01        | .204     | 3.32        | .127     | 16"         |          |
| 1500      | 3.342     | 16.7                                       | 6.84     | 9.62        | 1.74     | 6.10        | .556     | 4.30        | .232     | 3.56        | .145     | 16"         |          |
| 1600      | 3.565     | 17.8                                       | 7.73     | 10.3        | 1.96     | 6.51        | .628     | 4.59        | .262     | 3.79        | .163     | 2.91        | .084     |
| 1800      | 4.010     | 20.0                                       | 9.64     | 11.5        | 2.46     | 7.32        | .782     | 5.16        | .329     | 4.27        | .203     | 3.27        | .104     |
| 2000      | 4.456     | 22.2                                       | 11.6     | 12.8        | 2.97     | 8.14        | .953     | 5.73        | .396     | 4.74        | .247     | 3.63        | .127     |
| 2500      | 5.570     | 27.8                                       | 17.6     | 16.0        | 4.49     | 10.2        | 1.44     | 7.17        | .601     | 5.93        | .374     | 4.54        | .192     |
| 3000      | 6.684     |  |          | 19.2        | 6.30     | 12.2        | 2.02     | 8.60        | .842     | 7.11        | .525     | 5.45        | .270     |
| 3500      | 7.798     |  |          | 22.4        | 8.41     | 14.2        | 2.70     | 10.0        | 1.12     | 8.30        | .700     | 6.36        | .358     |
| 4000      | 8.912     |  |          | 25.7        | 10.8     | 16.3        | 3.46     | 11.5        | 1.44     | 9.48        | .896     | 7.26        | .459     |
| 4500      | 10.03     |  |          | 28.9        | 13.4     | 18.3        | 4.31     | 12.9        | 1.76     | 10.7        | 1.12     | 8.17        | .671     |
| 5000      | 11.14     |  |          |             |          | 20.4        | 5.23     | 14.3        | 2.18     | 11.9        | 1.36     | 9.08        | .695     |
| 6000      | 13.37     |  |          |             |          | 24.4        | 7.35     | 17.2        | 3.06     | 14.2        | 1.91     | 10.9        | .977     |
| 7000      | 15.60     |  |          |             |          | 28.5        | 9.80     | 20.1        | 4.08     | 16.6        | 2.54     | 12.7        | 1.30     |
| 8000      | 17.82     |  |          |             |          |             |          | 22.9        | 5.22     | 19.0        | 3.25     | 14.5        | 1.67     |
| 9000      | 20.05     |  |          |             |          |             |          | 25.8        | 6.51     | 21.3        | 4.06     | 16.3        | 2.08     |
| 10000     | 22.28     |  |          |             |          |             |          | 28.7        | 7.91     | 23.7        | 4.92     | 18.2        | 2.53     |
| 12000     | 26.74     |  |          |             |          |             |          |             |          | 28.5        | 6.92     | 21.8        | 3.55     |
| 14000     | 31.19     |  |          |             |          |             |          |             |          |             |          | 25.4        | 4.72     |
| 16000     | 35.65     |  |          |             |          |             |          |             |          |             |          | 29.1        | 6.06     |
| 18000     | 40.10     |  |          |             |          |             |          |             |          |             |          | 32.7        | 7.55     |
| 20000     | 44.56     |  |          |             |          |             |          |             |          |             |          |             |          |

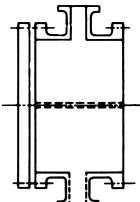
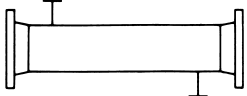
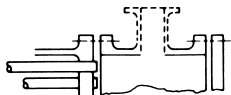
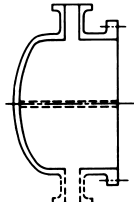
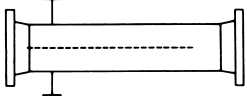
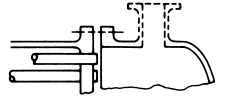
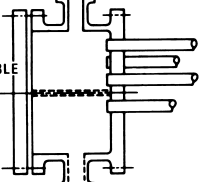
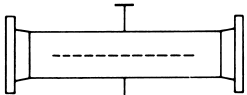
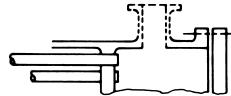
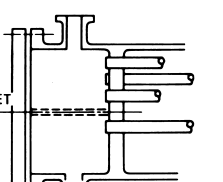

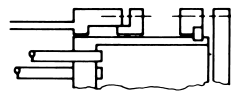
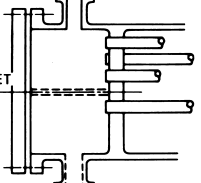
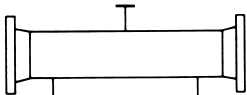
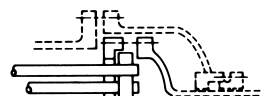
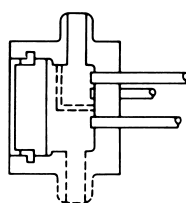
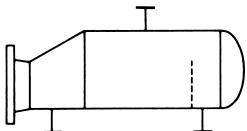
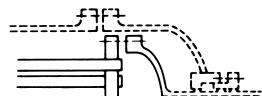
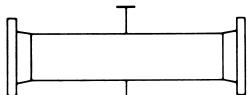
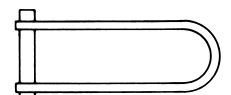
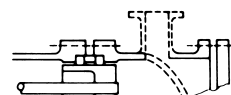
Reproduced by courtesy of the Lunkenheimer Company. Data are based on the Saph and Schoder formula:  $p = LQ^{1.86}/1435 D^5$   
[www.pipingguide.com](http://www.pipingguide.com)

# HEAT EXCHANGER NOMENCLATURE

## CHART H-1

REPRODUCED BY PERMISSION OF THE TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION

THREE LETTERS, SUCH AS AEW, BGP, etc. DESIGNATE THE BASIC CONSTRUCTION OF THE EXCHANGER. REFER TO 6.6.1, 'DATA NEEDED TO DESIGN EXCHANGER PIPING'

| FRONT END<br>STATIONARY HEAD TYPES |   | SHELL TYPES |   | REAR END<br>HEAD TYPES |   |
|------------------------------------|---|-------------|---|------------------------|---|
| A                                  |    | E           |    | L                      |    |
|                                    | CHANNEL<br>AND REMOVABLE COVER  |             | ONE PASS SHELL  |                        | FIXED TUBESHEET<br>LIKE "A" STATIONARY HEAD   |
|                                    |    |             |    |                        |    |
|                                    | BONNET INTEGRAL COVER   |             | TWO PASS SHELL<br>WITH LONGITUDINAL BAFFLE  |                        | FIXED TUBESHEET<br>LIKE "B" STATIONARY HEAD   |
|                                    |   |             |    |                        |    |
| C                                  | REMOVABLE<br>TUBE<br>BUNDLE<br>ONLY   | G           | SPLIT FLOW  | N                      | FIXED TUBESHEET<br>LIKE "N" STATIONARY HEAD   |
| N                                  |  | H           |   | P                      |    |
|                                    | CHANNEL INTEGRAL WITH TUBE-<br>SHEET AND REMOVABLE COVER                            |             | DOUBLE SPLIT FLOW   |                        | OUTSIDE PACKED<br>FLOATING HEAD   |
|                                    |  |             |  |                        |  |
| N                                  | FIXED<br>TUBESHEET<br>ONLY  | J           | DIVIDED FLOW  | S                      | FLOATING HEAD<br>WITH BACKING DEVICE  |
| D                                  |  | K           |  | T                      |  |
|                                    | SPECIAL HIGH PRESSURE CLOSURE   |             | KETTLE TYPE REBOILER  |                        | PULL THROUGH FLOATING HEAD  |
|                                    |   | X           |  | U                      |  |
|                                    |   |             | CROSS FLOW  | U                      | U-TUBE BUNDLE   |
|                                    |   |             |   | W                      |  |
|                                    |   |             |   | W                      | EXTERNALLY SEALED<br>FLOATING TUBESHEET   |

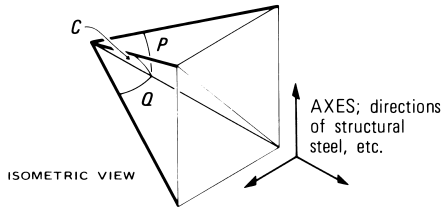
www.pipingguide.com

# MEASUREMENTS

ALL ANGLES IN THESE FORMULAS  
ARE EXPRESSED IN DEGREES OF ARC

# CHART M-1

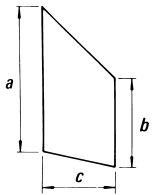
## COMPOUND ANGLES



Compound angle,  $C$ , is given by:

$$(\tan C)^2 = (\tan P)^2 + (\tan Q)^2$$

## TRAPEZOID

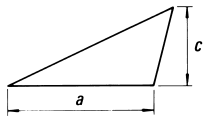


Trapezoid: A four-sided figure with two parallel sides, and the other two sides at any angle. Termed 'trapezium' in UK.

$$\text{AREA} = c(a + b)/2$$

If  $a = b$ , this formula applies to any parallelogram or rectangle.

## TRIANGLE



$$\text{AREA} = ac/2$$

## CIRCLE

Refer to table M-4 for numerical values of circumferences and areas of full circles

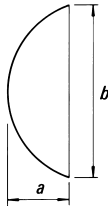
### FULL CIRCLE

$$\begin{aligned}\text{CIRCUMFERENCE} &= 2\pi r \\ &= 6.2831853 r \\ \text{AREA} &= \pi r^2 \\ &= 3.1415927 r^2\end{aligned}$$

### SECTOR (as shown)

$$\begin{aligned}\text{LENGTH OF ARC} &= l = \pi r Q/180 \\ &= 0.0174533 r Q \\ \text{AREA} &= \pi r^2 Q/360 \\ &= 0.00872664 r^2 Q\end{aligned}$$

## SEGMENT OF CIRCLE

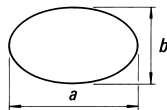


$$\begin{aligned}\text{DIAMETER} &= a + (b^2/4a) \\ \text{RADIUS} &= r = (a/2) + (b^2/8a) \\ \text{LENGTH OF ARC} &= l = (\pi r/90) \cdot \arccos[1 - (a/r)] \\ &= (\pi r/90) \cdot \arcsin[b/2r] \\ \text{where } \pi/90 &= 0.03490659\end{aligned}$$

$$\begin{aligned}\text{AREA} &= (rl - rb + ab)/2 \\ \text{NOTE: } \arccos[Q] &= \text{"angle in degrees whose cosine is } Q\text{"}, \text{ and} \\ \arcsin[Q] &= \text{"angle in degrees whose sine is } Q\text{"}.\end{aligned}$$

\*Valid for  $a$  positive and less than  $2r$ .

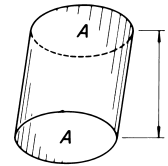
## ELLIPSE



$$\begin{aligned}\text{AREA} &= (\pi/4)(ab) \\ &= 0.7853982 (ab) \\ \text{CIRCUMFERENCE} &= \pi[(a^2 + b^2)/2]^{1/2} \text{ approximately}\end{aligned}$$

## PRISM

BASE OF ANY SHAPE; UPRIGHT OR SLOPING

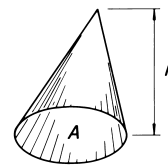


$$\begin{aligned}\text{AREA OF SECTION} &= A \\ \text{DISTANCE BETWEEN PARALLEL SECTIONS 'A' AND 'A' = } h \\ \text{VOLUME} &= hA\end{aligned}$$

NOTE: THIS FORMULA MAY BE APPLIED TO CYLINDRIC AND RECTANGULAR TANKS.

## CONE

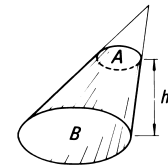
BASE OF ANY SHAPE; UPRIGHT OR SLOPING



$$\begin{aligned}\text{AREA OF BASE} &= A \\ \text{HEIGHT (measured at right angles to base)} &= h \\ \text{VOLUME} &= hA/3\end{aligned}$$

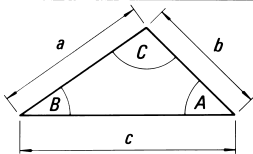
## FRUSTUM OF CONE

SECTION OF ANY SHAPE; UPRIGHT OR SLOPING



$$\begin{aligned}\text{AREAS OF PARALLEL FLAT SURFACES 'A' AND 'B' = } A \text{ and } B, \text{ respectively} \\ \text{DISTANCE BETWEEN SURFACES 'A' AND 'B' = } h \\ \text{VOLUME} &= (h/3) \cdot [A + B + (AB)^{1/2}]\end{aligned}$$

## TRIANGLES

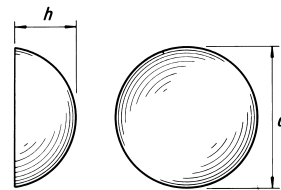


THESE FORMULAS MAY BE USED FOR ALL (FLAT) TRIANGLES

If  $\theta$  is between  $90^\circ$  and  $180^\circ$ ,  
 $\sin \theta = \sin(180^\circ - \theta)$ ,  $\cos \theta = -\cos(180^\circ - \theta)$   
(Thus values may be found in tables.)

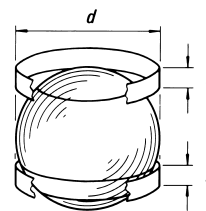
| KNOWN                                    | REQUIRED      | SOLUTION   |
|--|---------------|--|
| Two angles                               | Third angle   | $A = 180^\circ - (B + C)$                                |
| Three sides                              | Any angle     | $\cos A = (b^2 + c^2 - a^2)/2bc$                         |
|  | Area          | $\text{Area} = [s(s-a)(s-b)(s-c)]^{1/2}$ $s = (a+b+c)/2$ |
| Two sides and included angle             | Third side    | $c = (a^2 + b^2 - 2ab \cos C)^{1/2}$                     |
|  | Third angle   | $\tan A = (a \sin C)/(b - a \cos C)$                     |
|  | Area          | $(ab \sin C)/2$  |
| Two sides and excluded angle (ambiguous) | Third side    | $c = b \cos A \pm (a^2 - b^2 \sin^2 A)^{1/2}$            |
|  | Area          | $(b/2) \sin A [b \cos A \pm (a^2 - b^2 \sin^2 A)^{1/2}]$ |
| One side and adjacent angles             | Adjacent side | $c = a \sin C / \sin(B + C)$                             |
|  | Area          | $a^2 \cdot \sin B \cdot \sin C / [2 \sin(B + C)]$        |

## SPHERE



$$\begin{aligned}\text{RADIUS} &= r \\ \text{DIAMETER} &= d = 2r \\ \text{SURFACE AREA} &= \pi d^2 \\ &= 3.14159265 d^2 \\ \text{VOLUME} &= \pi d^3/6 \\ &= 0.5235988 d^3 \\ \text{VOLUME OF SEGMENT OF DEPTH } h &= (\pi h^2/3)(3r - h) \\ &= (1.0471976 h^2)(3r - h), \\ \text{where } h &\text{ is positive and less than } 2r.\end{aligned}$$

## AREA OF SPHERICAL CAP OR SLICE



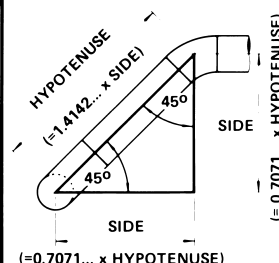
The area of the curved surface of the cap or the slice equals the area of the cylindric band of the same depth,  $h$ ; that is,  $\pi h d$ , no matter where the slice is taken, or how thick the slice or cap is.

## TABLES M-2

## HYPOTENUSE FOR $45^\circ$ TRIANGLES

VALUES COMPUTED TO  
NEAREST 1/16-INCH

| SIDE |         | HYPOTENUSE | SIDE    |   | HYPOTENUSE | SIDE |         | HYPOTENUSE | SIDE    |   | HYPOTENUSE |   |          |   |          |
|------|---------|------------|---------|---|------------|------|---------|------------|---------|---|------------|---|----------|---|----------|
| 0    | 0-1/16  | 0          | 0-1/16  | 0 | 3-3/16     | 0    | 4-1/2   | 0          | 6-5/16  | 0 | 8-15/16    | 0 | 9-7/16   | 0 | 13-3/8   |
| 0    | 0-1/8   | 0          | 0-3/16  | 0 | 3-1/4      | 0    | 4-5/8   | 0          | 6-3/8   | 0 | 9          | 0 | 9-1/2    | 0 | 13-7/16  |
| 0    | 0-3/16  | 0          | 0-1/4   | 0 | 3-5/16     | 0    | 4-11/16 | 0          | 6-7/16  | 0 | 9-1/8      | 0 | 9-9/16   | 0 | 13-1/2   |
| 0    | 0-1/4   | 0          | 0-3/8   | 0 | 3-3/8      | 0    | 4-3/4   | 0          | 6-1/2   | 0 | 9-3/16     | 0 | 9-5/8    | 0 | 13-5/8   |
| 0    | 0-5/16  | 0          | 0-7/16  | 0 | 3-7/16     | 0    | 4-7/8   | 0          | 6-9/16  | 0 | 9-1/4      | 0 | 9-11/16  | 0 | 13-11/16 |
| 0    | 0-3/8   | 0          | 0-1/2   | 0 | 3-1/2      | 0    | 4-15/16 | 0          | 6-5/8   | 0 | 9-3/8      | 0 | 9-3/4    | 0 | 13-13/16 |
| 0    | 0-7/16  | 0          | 0-5/8   | 0 | 3-9/16     | 0    | 5-1/16  | 0          | 6-11/16 | 0 | 9-7/16     | 0 | 9-13/16  | 0 | 13-7/8   |
| 0    | 0-1/2   | 0          | 0-11/16 | 0 | 3-5/8      | 0    | 5-1/8   | 0          | 6-3/4   | 0 | 9-9/16     | 0 | 9-7/8    | 0 | 13-15/16 |
| 0    | 0-9/16  | 0          | 0-13/16 | 0 | 3-11/16    | 0    | 5-3/16  | 0          | 6-13/16 | 0 | 9-5/8      | 0 | 9-15/16  | 0 | 14-1/16  |
| 0    | 0-5/8   | 0          | 0-7/8   | 0 | 3-3/4      | 0    | 5-5/16  | 0          | 6-7/8   | 0 | 9-3/4      | 0 | 10       | 0 | 14-1/8   |
| 0    | 0-11/16 | 0          | 1       | 0 | 3-13/16    | 0    | 5-3/8   | 0          | 6-15/16 | 0 | 9-13/16    | 0 | 10-1/16  | 0 | 14-1/4   |
| 0    | 0-3/4   | 0          | 1-1/16  | 0 | 3-7/8      | 0    | 5-1/2   | 0          | 7       | 0 | 9-7/8      | 0 | 10-1/8   | 0 | 14-5/16  |
| 0    | 0-13/16 | 0          | 1-1/8   | 0 | 3-15/16    | 0    | 5-9/16  | 0          | 7-1/16  | 0 | 10         | 0 | 10-3/16  | 0 | 14-7/16  |
| 0    | 0-7/8   | 0          | 1-1/4   | 0 | 4          | 0    | 5-11/16 | 0          | 7-1/8   | 0 | 10-1/16    | 0 | 10-1/4   | 0 | 14-1/2   |
| 0    | 0-15/16 | 0          | 1-5/16  | 0 | 4-1/16     | 0    | 5-3/4   | 0          | 7-3/16  | 0 | 10-3/16    | 0 | 10-5/16  | 0 | 14-9/16  |
| 0    | 1       | 0          | 1-7/16  | 0 | 4-1/8      | 0    | 5-13/16 | 0          | 7-1/4   | 0 | 10-1/4     | 0 | 10-3/8   | 0 | 14-11/16 |
| 0    | 1-1/16  | 0          | 1-1/2   | 0 | 4-3/16     | 0    | 5-15/16 | 0          | 7-5/16  | 0 | 10-5/16    | 0 | 10-7/16  | 0 | 14-3/4   |
| 0    | 1-1/8   | 0          | 1-9/16  | 0 | 4-1/4      | 0    | 6       | 0          | 7-3/8   | 0 | 10-7/16    | 0 | 10-1/2   | 0 | 14-7/8   |
| 0    | 1-3/16  | 0          | 1-11/16 | 0 | 4-5/16     | 0    | 6-1/8   | 0          | 7-7/16  | 0 | 10-1/2     | 0 | 10-9/16  | 0 | 14-15/16 |
| 0    | 1-1/4   | 0          | 1-3/4   | 0 | 4-3/8      | 0    | 6-3/16  | 0          | 7-1/2   | 0 | 10-5/8     | 0 | 10-5/8   | 0 | 15       |
| 0    | 1-5/16  | 0          | 1-7/8   | 0 | 4-7/16     | 0    | 6-1/4   | 0          | 7-9/16  | 0 | 10-11/16   | 0 | 10-11/16 | 0 | 15-1/8   |
| 0    | 1-3/8   | 0          | 1-15/16 | 0 | 4-1/2      | 0    | 6-3/8   | 0          | 7-5/8   | 0 | 10-13/16   | 0 | 10-3/4   | 0 | 15-3/16  |
| 0    | 1-7/16  | 0          | 2-1/16  | 0 | 4-9/16     | 0    | 6-7/16  | 0          | 7-11/16 | 0 | 10-7/8     | 0 | 10-13/16 | 0 | 15-5/16  |
| 0    | 1-1/2   | 0          | 2-1/8   | 0 | 4-5/8      | 0    | 6-9/16  | 0          | 7-3/4   | 0 | 10-15/16   | 0 | 10-7/8   | 0 | 15-3/8   |
| 0    | 1-9/16  | 0          | 2-3/16  | 0 | 4-11/16    | 0    | 6-5/8   | 0          | 7-13/16 | 0 | 11-1/16    | 0 | 10-15/16 | 0 | 15-7/16  |
| 0    | 1-5/8   | 0          | 2-5/16  | 0 | 4-3/4      | 0    | 6-11/16 | 0          | 7-7/8   | 0 | 11-1/8     | 0 | 11       | 0 | 15-9/16  |
| 0    | 1-11/16 | 0          | 2-3/8   | 0 | 4-13/16    | 0    | 6-13/16 | 0          | 7-15/16 | 0 | 11-1/4     | 0 | 11-1/16  | 0 | 15-5/8   |
| 0    | 1-3/4   | 0          | 2-1/2   | 0 | 4-7/8      | 0    | 6-7/8   | 0          | 8       | 0 | 11-5/16    | 0 | 11-1/8   | 0 | 15-3/4   |
| 0    | 1-13/16 | 0          | 2-9/16  | 0 | 4-15/16    | 0    | 7       | 0          | 8-1/16  | 0 | 11-3/8     | 0 | 11-3/16  | 0 | 15-13/16 |
| 0    | 1-7/8   | 0          | 2-5/8   | 0 | 5          | 0    | 7-1/16  | 0          | 8-1/8   | 0 | 11-1/2     | 0 | 11-1/4   | 0 | 15-15/16 |
| 0    | 1-15/16 | 0          | 2-3/4   | 0 | 5-1/16     | 0    | 7-3/16  | 0          | 8-3/16  | 0 | 11-9/16    | 0 | 11-5/16  | 0 | 16       |
| 0    | 2       | 0          | 2-13/16 | 0 | 5-1/8      | 0    | 7-1/4   | 0          | 8-1/4   | 0 | 11-11/16   | 0 | 11-3/8   | 0 | 16-1/16  |
| 0    | 2-1/16  | 0          | 2-15/16 | 0 | 5-3/16     | 0    | 7-5/16  | 0          | 8-5/16  | 0 | 11-3/4     | 0 | 11-7/16  | 0 | 16-3/16  |
| 0    | 2-1/8   | 0          | 3       | 0 | 5-1/4      | 0    | 7-7/16  | 0          | 8-3/8   | 0 | 11-7/8     | 0 | 11-1/2   | 0 | 16-1/4   |
| 0    | 2-3/16  | 0          | 3-1/16  | 0 | 5-5/16     | 0    | 7-1/2   | 0          | 8-7/16  | 0 | 11-15/16   | 0 | 11-9/16  | 0 | 16-3/8   |
| 0    | 2-1/4   | 0          | 3-3/16  | 0 | 5-3/8      | 0    | 7-5/8   | 0          | 8-1/2   | 0 | 12         | 0 | 11-5/8   | 0 | 16-7/16  |
| 0    | 2-5/16  | 0          | 3-1/4   | 0 | 5-7/16     | 0    | 7-11/16 | 0          | 8-9/16  | 0 | 12-1/8     | 0 | 11-11/16 | 0 | 16-1/2   |
| 0    | 2-3/8   | 0          | 3-3/8   | 0 | 5-1/2      | 0    | 7-3/4   | 0          | 8-5/8   | 0 | 12-3/16    | 0 | 11-3/4   | 0 | 16-5/8   |
| 0    | 2-7/16  | 0          | 3-7/16  | 0 | 5-9/16     | 0    | 7-7/8   | 0          | 8-11/16 | 0 | 12-5/16    | 0 | 11-13/16 | 0 | 16-11/16 |
| 0    | 2-1/2   | 0          | 3-9/16  | 0 | 5-5/8      | 0    | 7-15/16 | 0          | 8-3/4   | 0 | 12-3/8     | 0 | 11-7/8   | 0 | 16-13/16 |
| 0    | 2-9/16  | 0          | 3-5/8   | 0 | 5-11/16    | 0    | 8-1/16  | 0          | 8-13/16 | 0 | 12-7/16    | 0 | 11-15/16 | 0 | 16-7/8   |
| 0    | 2-5/8   | 0          | 3-11/16 | 0 | 5-3/4      | 0    | 8-1/8   | 0          | 8-7/8   | 0 | 12-9/16    | 0 | 12       | 0 | 17       |
| 0    | 2-11/16 | 0          | 3-13/16 | 0 | 5-13/16    | 0    | 8-1/4   | 0          | 8-15/16 | 0 | 12-5/8     | 0 | 12-1/16  | 0 | 17-5/16  |
| 0    | 2-3/4   | 0          | 3-7/8   | 0 | 5-7/8      | 0    | 8-5/16  | 0          | 9       | 0 | 12-3/4     | 0 | 12-1/8   | 0 | 17-1/8   |
| 0    | 2-13/16 | 0          | 4       | 0 | 5-15/16    | 0    | 8-3/8   | 0          | 9-1/16  | 0 | 12-13/16   | 0 | 12-3/16  | 0 | 17-1/4   |
| 0    | 2-7/8   | 0          | 4-1/16  | 0 | 6          | 0    | 8-1/2   | 0          | 9-1/8   | 0 | 12-7/8     | 0 | 12-1/4   | 0 | 17-5/16  |
| 0    | 2-15/16 | 0          | 4-1/8   | 0 | 6-1/16     | 0    | 8-9/16  | 0          | 9-3/16  | 0 | 13         | 0 | 12-5/16  | 0 | 17-7/16  |
| 0    | 3       | 0          | 4-1/4   | 0 | 6-1/8      | 0    | 8-11/16 | 0          | 9-1/4   | 0 | 13-1/16    | 0 | 12-3/8   | 0 | 17-1/2   |
| 0    | 3-1/16  | 0          | 4-5/16  | 0 | 6-3/16     | 0    | 8-3/4   | 0          | 9-5/16  | 0 | 13-3/16    | 0 | 12-7/16  | 0 | 17-9/16  |
| 0    | 3-1/8   | 0          | 4-7/16  | 0 | 6-1/4      | 0    | 8-13/16 | 0          | 9-3/8   | 0 | 13-1/4     | 0 | 12-1/2   | 0 | 17-11/16 |



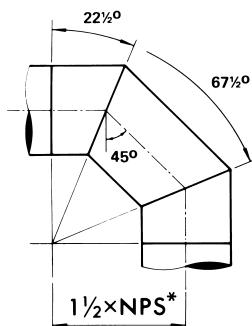
## FEET

| SIDE       | HYPOTENUSE  |
|------------|-------------|
| 1 0        | 1 4-31/32   |
| 2 0        | 2 9-15/16   |
| 3 0        | 4 2-29/32   |
| 4 0        | 5 7-7/8     |
| 5 0        | 7 0-27/32   |
| 6 0        | 8 5-13/16   |
| 7 0        | 9 10-25/32  |
| 8 0        | 11 3-3/4    |
| 9 0        | 12 8-3/4    |
| 10 0       | 14 1-23/32  |
| 11 0       | 15 6-11/16  |
| 12 0       | 16 11-21/32 |
| 13 0       | 18 4-5/8    |
| 14 0       | 19 9-19/32  |
| 15 0       | 21 2-9/16   |
| 0 8-1/2    | 1 0         |
| 1 4-31/32  | 2 0         |
| 2 1-15/32  | 3 0         |
| 2 9-15/16  | 4 0         |
| 3 6-7/16   | 5 0         |
| 4 2-29/32  | 6 0         |
| 4 11-13/32 | 7 0         |
| 5 7-7/8    | 8 0         |
| 6 4-3/8    | 9 0         |
| 7 0-27/32  | 10 0        |
| 7 9-11/32  | 11 0        |
| 8 5-13/16  | 12 0        |
| 9 2-5/16   | 13 0        |
| 9 10-25/32 | 14 0        |
| 10 7-9/32  | 15 0        |

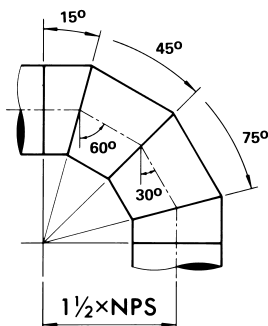
## CONSTRUCTION OF MITERS

## TANGENT LENGTHS FOR BENDS

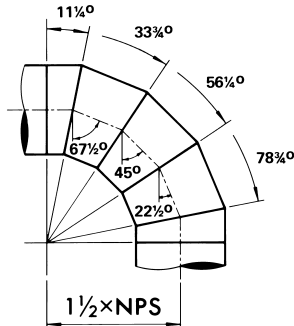
### 3-PIECE



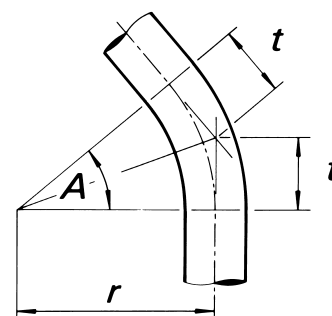
**4-PIECE**



## 5-PIECE



\* NPS = NOMINAL PIPE SIZE (INCHES)



**A = Angle of bend**

### GENERAL FORMULA

$$t = r.\tan(A/2)$$

(Valid for 'A' less than 180°)

# MILLIMETERS CONVERTED TO FEET AND INCHES

# TABLES M-3

| mm | ft-in.(fraction) | mm  | ft-in.(fraction) | mm  | ft-in.(fraction) | mm  | ft-in.(fraction) | mm  | ft-in.(fraction) | mm  | ft-in.(fraction) | mm  | ft-in.(fraction) |
|----|------------------|-----|------------------|-----|------------------|-----|------------------|-----|------------------|-----|------------------|-----|------------------|
| 1  | 0- 0.04 [3/64]   | 81  | 0- 3.19 [31/16]  | 161 | 0- 6.34 [11/32]  | 241 | 0- 9.49 [31/64]  | 321 | 1- 0.64 [41/64]  | 401 | 1- 3.79 [25/32]  | 481 | 1- 6.94 [15/16]  |
| 2  | 0- 0.08 [5/64]   | 82  | 0- 3.23 [15/64]  | 162 | 0- 6.38 [3/8]    | 242 | 0- 9.53 [17/32]  | 322 | 1- 0.68 [43/64]  | 402 | 1- 3.83 [53/64]  | 482 | 1- 6.98 [31/32]  |
| 3  | 0- 0.12 [1/8]    | 83  | 0- 3.27 [17/64]  | 163 | 0- 6.42 [27/64]  | 243 | 0- 9.57 [9/16]   | 323 | 1- 0.72 [23/32]  | 403 | 1- 3.87 [55/64]  | 483 | 1- 7.02 [1/64]   |
| 4  | 0- 0.16 [5/32]   | 84  | 0- 3.31 [5/16]   | 164 | 0- 6.46 [29/64]  | 244 | 0- 9.61 [39/64]  | 324 | 1- 0.76 [3/4]    | 404 | 1- 3.91 [29/32]  | 484 | 1- 7.06 [1/16]   |
| 5  | 0- 0.20 [13/64]  | 85  | 0- 3.35 [11/32]  | 165 | 0- 6.50 [1/2]    | 245 | 0- 9.65 [41/64]  | 325 | 1- 0.80 [51/64]  | 405 | 1- 3.94 [15/16]  | 485 | 1- 7.09 [3/32]   |
| 6  | 0- 0.24 [15/64]  | 86  | 0- 3.39 [25/64]  | 166 | 0- 6.54 [17/32]  | 246 | 0- 9.69 [11/16]  | 326 | 1- 0.83 [53/64]  | 406 | 1- 3.98 [63/64]  | 486 | 1- 7.13 [9/64]   |
| 7  | 0- 0.28 [9/32]   | 87  | 0- 3.43 [27/64]  | 167 | 0- 6.57 [37/64]  | 247 | 0- 9.72 [23/32]  | 327 | 1- 0.87 [7/8]    | 407 | 1- 4.02 [1/32]   | 487 | 1- 7.17 [11/64]  |
| 8  | 0- 0.31 [5/16]   | 88  | 0- 3.46 [15/32]  | 168 | 0- 6.61 [39/64]  | 248 | 0- 9.76 [49/64]  | 328 | 1- 0.91 [29/32]  | 408 | 1- 4.06 [1/16]   | 488 | 1- 7.21 [7/32]   |
| 9  | 0- 0.35 [23/64]  | 89  | 0- 3.50 [1/2]    | 169 | 0- 6.65 [21/32]  | 249 | 0- 9.80 [51/64]  | 329 | 1- 0.95 [61/64]  | 409 | 1- 4.10 [7/64]   | 489 | 1- 7.25 [1/4]    |
| 10 | 0- 0.39 [25/64]  | 90  | 0- 3.54 [35/64]  | 170 | 0- 6.69 [11/16]  | 250 | 0- 9.84 [27/32]  | 330 | 1- 0.99 [63/64]  | 410 | 1- 4.14 [9/64]   | 490 | 1- 7.29 [19/64]  |
| 11 | 0- 0.43 [7/16]   | 91  | 0- 3.58 [37/64]  | 171 | 0- 6.73 [47/64]  | 251 | 0- 9.88 [7/8]    | 331 | 1- 1.03 [1/32]   | 411 | 1- 4.18 [3/16]   | 491 | 1- 7.33 [21/64]  |
| 12 | 0- 0.47 [15/32]  | 92  | 0- 3.62 [5/8]    | 172 | 0- 6.77 [49/64]  | 252 | 0- 9.92 [59/64]  | 332 | 1- 1.07 [5/64]   | 412 | 1- 4.22 [7/32]   | 492 | 1- 7.37 [3/8]    |
| 13 | 0- 0.51 [33/64]  | 93  | 0- 3.66 [21/32]  | 173 | 0- 6.81 [13/16]  | 253 | 0- 9.96 [61/64]  | 333 | 1- 1.11 [7/64]   | 413 | 1- 4.26 [17/64]  | 493 | 1- 7.41 [13/32]  |
| 14 | 0- 0.55 [35/64]  | 94  | 0- 3.70 [45/64]  | 174 | 0- 6.85 [27/32]  | 254 | 0-10.00          | 334 | 1- 1.15 [5/32]   | 414 | 1- 4.30 [19/64]  | 494 | 1- 7.45 [29/64]  |
| 15 | 0- 0.59 [19/32]  | 95  | 0- 3.74 [47/64]  | 175 | 0- 6.89 [57/64]  | 255 | 0-10.04 [3/64]   | 335 | 1- 1.19 [3/16]   | 415 | 1- 4.34 [11/32]  | 495 | 1- 7.49 [31/64]  |
| 16 | 0- 0.63 [5/8]    | 96  | 0- 3.78 [25/32]  | 176 | 0- 6.93 [59/64]  | 256 | 0-10.08 [5/64]   | 336 | 1- 1.23 [15/64]  | 416 | 1- 4.38 [3/8]    | 496 | 1- 7.53 [17/32]  |
| 17 | 0- 0.67 [43/64]  | 97  | 0- 3.82 [13/16]  | 177 | 0- 6.97 [31/32]  | 257 | 0-10.12 [1/8]    | 337 | 1- 1.27 [17/64]  | 417 | 1- 4.42 [27/64]  | 497 | 1- 7.57 [9/16]   |
| 18 | 0- 0.71 [45/64]  | 98  | 0- 3.86 [55/64]  | 178 | 0- 7.01 [1/64]   | 258 | 0-10.16 [5/32]   | 338 | 1- 1.31 [5/16]   | 418 | 1- 4.46 [29/64]  | 498 | 1- 7.61 [39/64]  |
| 19 | 0- 0.75 [3/4]    | 99  | 0- 3.90 [57/64]  | 179 | 0- 7.05 [3/64]   | 259 | 0-10.20 [13/64]  | 339 | 1- 1.35 [11/32]  | 419 | 1- 4.50 [1/2]    | 499 | 1- 7.65 [41/64]  |
| 20 | 0- 0.79 [25/32]  | 100 | 0- 3.94 [15/16]  | 180 | 0- 7.09 [3/32]   | 260 | 0-10.24 [15/64]  | 340 | 1- 1.39 [25/64]  | 420 | 1- 4.54 [17/32]  | 500 | 1- 7.69 [11/16]  |
| 21 | 0- 0.83 [53/64]  | 101 | 0- 3.98 [31/32]  | 181 | 0- 7.13 [1/8]    | 261 | 0-10.28 [9/32]   | 341 | 1- 1.43 [27/64]  | 421 | 1- 4.57 [37/64]  | 501 | 1- 7.72 [23/32]  |
| 22 | 0- 0.87 [55/64]  | 102 | 0- 4.02 [1/64]   | 182 | 0- 7.17 [11/64]  | 262 | 0-10.31 [5/16]   | 342 | 1- 1.46 [39/64]  | 422 | 1- 4.61 [59/64]  | 502 | 1- 7.76 [49/64]  |
| 23 | 0- 0.91 [29/32]  | 103 | 0- 4.06 [1/16]   | 183 | 0- 7.20 [13/64]  | 263 | 0-10.35 [23/64]  | 343 | 1- 1.50 [1/2]    | 423 | 1- 4.65 [21/32]  | 503 | 1- 7.80 [51/64]  |
| 24 | 0- 0.94 [15/16]  | 104 | 0- 4.09 [3/32]   | 184 | 0- 7.24 [1/4]    | 264 | 0-10.39 [25/64]  | 344 | 1- 1.54 [35/64]  | 424 | 1- 4.69 [11/16]  | 504 | 1- 7.84 [27/32]  |
| 25 | 0- 0.98 [63/64]  | 105 | 0- 4.13 [9/64]   | 185 | 0- 7.28 [9/32]   | 265 | 0-10.43 [7/16]   | 345 | 1- 1.58 [37/64]  | 425 | 1- 4.73 [47/64]  | 505 | 1- 7.88 [7/8]    |
| 26 | 0- 1.02 [1/32]   | 106 | 0- 4.17 [11/64]  | 186 | 0- 7.32 [21/64]  | 266 | 0-10.47 [15/32]  | 346 | 1- 1.62 [5/8]    | 426 | 1- 4.77 [49/64]  | 506 | 1- 7.92 [59/64]  |
| 27 | 0- 1.06 [1/16]   | 107 | 0- 4.21 [7/32]   | 187 | 0- 7.36 [23/64]  | 267 | 0-10.51 [33/64]  | 347 | 1- 1.66 [21/32]  | 427 | 1- 4.81 [13/16]  | 507 | 1- 7.96 [61/64]  |
| 28 | 0- 1.10 [7/64]   | 108 | 0- 4.25 [1/4]    | 188 | 0- 7.40 [13/32]  | 268 | 0-10.55 [35/64]  | 348 | 1- 1.70 [45/64]  | 428 | 1- 4.85 [27/32]  | 508 | 1- 8.00          |
| 29 | 0- 1.14 [9/64]   | 109 | 0- 4.29 [19/64]  | 189 | 0- 7.44 [7/16]   | 269 | 0-10.59 [19/32]  | 349 | 1- 1.74 [47/64]  | 429 | 1- 4.89 [57/64]  | 509 | 1- 8.04 [3/64]   |
| 30 | 0- 1.18 [3/16]   | 110 | 0- 4.33 [21/64]  | 190 | 0- 7.48 [31/64]  | 270 | 0-10.63 [5/8]    | 350 | 1- 1.78 [25/32]  | 430 | 1- 4.93 [59/64]  | 510 | 1- 8.08 [5/64]   |
| 31 | 0- 1.22 [7/32]   | 111 | 0- 4.37 [3/8]    | 191 | 0- 7.52 [33/64]  | 271 | 0-10.67 [43/64]  | 351 | 1- 1.82 [13/16]  | 431 | 1- 4.97 [31/32]  | 511 | 1- 8.12 [1/8]    |
| 32 | 0- 1.26 [17/64]  | 112 | 0- 4.41 [13/32]  | 192 | 0- 7.56 [9/16]   | 272 | 0-10.71 [45/64]  | 352 | 1- 1.86 [55/64]  | 432 | 1- 5.01 [1/64]   | 512 | 1- 8.16 [5/32]   |
| 33 | 0- 1.30 [19/64]  | 113 | 0- 4.45 [29/64]  | 193 | 0- 7.60 [19/32]  | 273 | 0-10.75 [3/4]    | 353 | 1- 1.90 [57/64]  | 433 | 1- 5.05 [3/32]   | 513 | 1- 8.20 [13/64]  |
| 34 | 0- 1.34 [11/32]  | 114 | 0- 4.49 [31/64]  | 194 | 0- 7.64 [41/64]  | 274 | 0-10.79 [25/32]  | 354 | 1- 1.94 [15/16]  | 434 | 1- 5.09 [3/32]   | 514 | 1- 8.24 [15/64]  |
| 35 | 0- 1.38 [3/8]    | 115 | 0- 4.53 [17/32]  | 195 | 0- 7.68 [43/64]  | 275 | 0-10.83 [53/64]  | 355 | 1- 1.98 [31/32]  | 435 | 1- 5.13 [1/8]    | 515 | 1- 8.28 [9/32]   |
| 36 | 0- 1.42 [27/64]  | 116 | 0- 4.57 [9/16]   | 196 | 0- 7.72 [23/32]  | 276 | 0-10.87 [55/64]  | 356 | 1- 2.02 [1/64]   | 436 | 1- 5.17 [11/64]  | 516 | 1- 8.31 [5/16]   |
| 37 | 0- 1.46 [29/64]  | 117 | 0- 4.61 [39/64]  | 197 | 0- 7.76 [3/4]    | 277 | 0-10.91 [29/32]  | 357 | 1- 2.06 [1/16]   | 437 | 1- 5.20 [13/64]  | 517 | 1- 8.35 [23/64]  |
| 38 | 0- 1.50 [1/2]    | 118 | 0- 4.65 [41/64]  | 198 | 0- 7.80 [51/64]  | 278 | 0-10.94 [15/16]  | 358 | 1- 2.09 [3/32]   | 438 | 1- 5.24 [1/4]    | 518 | 1- 8.39 [25/64]  |
| 39 | 0- 1.54 [17/32]  | 119 | 0- 4.69 [11/16]  | 199 | 0- 7.83 [53/64]  | 279 | 0-10.98 [63/64]  | 359 | 1- 2.13 [9/64]   | 439 | 1- 5.28 [9/32]   | 519 | 1- 8.43 [7/16]   |
| 40 | 0- 1.57 [37/64]  | 120 | 0- 4.72 [23/32]  | 200 | 0- 7.87 [7/8]    | 280 | 0-11.02 [1/32]   | 360 | 1- 2.17 [11/64]  | 440 | 1- 5.32 [21/64]  | 520 | 1- 8.47 [15/32]  |
| 41 | 0- 1.61 [39/64]  | 121 | 0- 4.76 [49/64]  | 201 | 0- 7.91 [29/32]  | 281 | 0-11.06 [1/16]   | 361 | 1- 2.21 [7/32]   | 441 | 1- 5.36 [23/64]  | 521 | 1- 8.51 [33/64]  |
| 42 | 0- 1.65 [21/32]  | 122 | 0- 4.80 [51/64]  | 202 | 0- 7.95 [61/64]  | 282 | 0-11.10 [7/64]   | 362 | 1- 2.25 [1/4]    | 442 | 1- 5.40 [13/32]  | 522 | 1- 8.55 [35/64]  |
| 43 | 0- 1.69 [11/16]  | 123 | 0- 4.84 [27/32]  | 203 | 0- 7.99 [63/64]  | 283 | 0-11.14 [9/64]   | 363 | 1- 2.29 [19/64]  | 443 | 1- 5.44 [7/16]   | 523 | 1- 8.59 [19/32]  |
| 44 | 0- 1.73 [47/64]  | 124 | 0- 4.88 [7/8]    | 204 | 0- 8.03 [13/32]  | 284 | 0-11.18 [3/16]   | 364 | 1- 2.33 [21/64]  | 444 | 1- 5.48 [31/64]  | 524 | 1- 8.63 [5/8]    |
| 45 | 0- 1.77 [49/64]  | 125 | 0- 4.92 [59/64]  | 205 | 0- 8.07 [5/64]   | 285 | 0-11.22 [7/32]   | 365 | 1- 2.37 [3/8]    | 445 | 1- 5.52 [33/64]  | 525 | 1- 8.67 [43/64]  |
| 46 | 0- 1.81 [13/16]  | 126 | 0- 4.96 [61/64]  | 206 | 0- 8.11 [7/64]   | 286 | 0-11.26 [17/64]  | 366 | 1- 2.41 [13/32]  | 446 | 1- 5.56 [9/16]   | 526 | 1- 8.71 [45/64]  |
| 47 | 0- 1.85 [27/32]  | 127 | 0- 5.00          | 207 | 0- 8.15 [5/32]   | 287 | 0-11.30 [19/64]  | 367 | 1- 2.45 [29/64]  | 447 | 1- 5.60 [19/32]  | 527 | 1- 8.75 [3/4]    |
| 48 | 0- 1.89 [57/64]  | 128 | 0- 5.04 [3/64]   | 208 | 0- 8.19 [3/16]   | 288 | 0-11.34 [11/32]  | 368 | 1- 2.49 [31/64]  | 448 | 1- 5.64 [41/64]  | 528 | 1- 8.79 [25/32]  |
| 49 | 0- 1.93 [59/64]  | 129 | 0- 5.08 [5/64]   | 209 | 0- 8.23 [15/64]  | 289 | 0-11.38 [3/8]    | 369 | 1- 2.53 [17/32]  | 449 | 1- 5.68 [43/64]  | 529 | 1- 8.83 [53/64]  |
| 50 | 0- 1.97 [31/32]  | 130 | 0- 5.12 [1/8]    | 210 | 0- 8.27 [17/64]  | 290 | 0-11.42 [27/64]  | 370 | 1- 2.57 [9/16]   | 450 | 1- 5.72 [23/32]  | 530 | 1- 8.87 [55/64]  |
| 51 | 0- 2.01 [1/64]   | 131 | 0- 5.16 [5/32]   | 211 | 0- 8.31 [5/16]   | 291 | 0-11.46 [29/64]  | 371 | 1- 2.61 [39/64]  | 451 | 1- 5.76 [3/4]    | 531 | 1- 8.91 [29/32]  |
| 52 | 0- 2.05 [3/64]   | 132 | 0- 5.20 [13/64]  | 212 | 0- 8.35 [11/32]  | 292 | 0-11.50 [1/2]    | 372 | 1- 2.65 [41/64]  | 452 | 1- 5.80 [51/64]  | 532 | 1- 8.94 [15/16]  |
| 53 | 0- 2.09 [3/32]   | 133 | 0- 5.24 [15/64]  | 213 | 0- 8.39 [25/64]  | 293 | 0-11.54 [17/32]  | 373 | 1- 2.69 [11/16]  | 453 | 1- 5.84 [53/64]  | 533 | 1- 8.98 [63/64]  |
| 54 | 0- 2.13 [1/8]    | 134 | 0- 5.28 [9/32]   | 214 | 0- 8.43 [27/64]  | 294 | 0-11.57 [37/64]  | 374 | 1- 2.72 [23/32]  | 454 | 1- 5.87 [7/8]    | 534 | 1- 9.02 [1/32]   |
| 55 | 0- 2.17 [11/64]  | 135 | 0- 5.31 [5/16]   | 215 | 0- 8.46 [15/32]  | 295 | 0-11.61 [39/64]  | 375 | 1- 2.76 [49/64]  | 455 | 1- 5.91 [29/32]  | 535 | 1- 9.06 [1/16]   |
| 56 | 0- 2.20 [13/64]  | 136 | 0- 5.35 [23/64]  | 216 | 0- 8.50 [1/2]    | 296 | 0-11.65 [21/32]  | 376 | 1- 2.80 [51/64]  | 456 | 1- 5.95 [61/64]  | 536 | 1- 9.10 [7/64]   |
| 57 | 0- 2.24 [1/4]    | 137 | 0- 5.39 [25/64]  | 217 | 0- 8.54 [35/64]  | 297 | 0-11.69 [11/16]  | 377 | 1- 2.84 [27/32]  | 457 | 1- 5.99 [63/64]  | 537 | 1- 9.14 [9/64]   |
| 58 | 0- 2.28 [9/32]   | 138 | 0- 5.43 [7/16]   | 218 | 0- 8.58 [37/64]  | 298 | 0-11.73 [47/64]  | 378 | 1- 2.88 [7/8]    | 458 | 1- 6.03 [1/32]   | 538 | 1- 9.18 [3/16]   |
| 59 | 0- 2.32 [21/64]  | 139 | 0- 5.47 [15/32]  | 219 | 0- 8.62 [5/8]    | 299 | 0-11.77 [49/64]  | 379 | 1- 2.92 [59/64]  | 459 | 1- 6.07 [5/64]   | 539 | 1- 9.22 [7/32]   |
| 60 | 0- 2.36 [23/64]  | 140 | 0- 5.51 [33/64]  | 220 | 0- 8.66 [21/32]  | 300 | 0-11.81 [13/16]  | 380 | 1- 2.96 [61/64]  | 460 | 1- 6.11 [7/64]   | 540 | 1- 9.26 [17/64]  |
| 61 | 0- 2.40 [13/32]  | 141 | 0- 5.55 [35/64]  | 221 | 0- 8.70 [45/64]  | 301 | 0-11.85 [27/32]  | 381 | 1- 3.00          | 461 | 1- 6.15 [5/32]   | 541 | 1- 9.30 [19/64]  |
| 62 | 0- 2.44 [7/16]   | 142 | 0- 5.59 [19/32]  | 222 | 0- 8.74 [47/64]  | 302 | 0-11.89 [57/64]  | 382 | 1- 3.04 [3/64]   | 462 | 1- 6.19 [3/16]   | 542 | 1- 9.34 [11/32]  |
| 63 | 0- 2.48 [31/64]  | 143 | 0- 5.63 [5/8]    | 223 | 0- 8.78 [25/32]  | 303 | 0-11.93 [59/64]  | 383 | 1- 3.08 [5/64]   | 463 | 1- 6.23 [15/64]  | 543 | 1- 9.38 [3/8]    |
| 64 | 0- 2.52 [33/64]  | 144 | 0- 5.67 [43/64]  | 224 | 0- 8.82 [13/16]  | 304 | 0-11.97 [31/32]  | 384 | 1- 3.12 [1/8]    | 464 | 1- 6.27 [17/64]  | 544 | 1- 9.42 [27/64]  |
| 65 | 0- 2.56 [9/16]   | 145 | 0- 5.71 [45/64]  | 225 | 0- 8.86 [55/64]  | 305 | 1- 0.01 [1/64]   | 385 | 1- 3.16 [5/32]   | 465 | 1- 6.31 [5/16]   | 545 | 1- 9.46 [29/64]  |
| 66 | 0- 2.60 [19/32]  | 146 | 0- 5.75 [3/4]    | 226 | 0- 8.90 [57/64]  | 306 | 1- 0.05 [3/64]   | 386 | 1- 3.20 [13/64]  | 466 | 1- 6.35 [11/32]  | 546 | 1- 9.50 [1/2]    |
| 67 | 0- 2.64 [41/64]  | 147 | 0- 5.79 [25/32]  | 227 | 0- 8.94 [15/16]  | 307 | 1- 0.09 [3/32]   | 387 | 1- 3.24 [15/64]  | 467 |                  |     |                  |

# MILLIMETERS CONVERTED TO FEET AND INCHES

# TABLES M-3

| mm  | ft-in.(fraction) | mm  | ft-in.(fraction) | mm  | ft-in.(fraction) | mm  | ft-in.(fraction) | mm  | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) |
|-----|------------------|-----|------------------|-----|------------------|-----|------------------|-----|------------------|------|------------------|------|------------------|
| 561 | 1-10.09 [3/32]   | 641 | 2- 1.24 [15/64]  | 721 | 2- 4.39 [25/64]  | 801 | 2- 7.54 [17/32]  | 881 | 2-10.69 [11/16]  | 961  | 3- 1.83 [53/64]  | 1041 | 3- 4.98 [63/64]  |
| 562 | 1-10.13 [1/8]    | 642 | 2- 1.28 [9/32]   | 722 | 2- 4.43 [27/64]  | 802 | 2- 7.57 [37/64]  | 882 | 2-10.72 [23/32]  | 962  | 3- 1.87 [7/8]    | 1042 | 3- 5.02 [1/32]   |
| 563 | 1-10.17 [11/64]  | 643 | 2- 1.31 [5/16]   | 723 | 2- 4.46 [15/32]  | 803 | 2- 7.61 [39/64]  | 883 | 2-10.76 [49/64]  | 963  | 3- 1.91 [29/32]  | 1043 | 3- 5.06 [1/16]   |
| 564 | 1-10.20 [13/64]  | 644 | 2- 1.35 [23/64]  | 724 | 2- 4.50 [1/2]    | 804 | 2- 7.65 [21/32]  | 884 | 2-10.80 [51/64]  | 964  | 3- 1.95 [61/64]  | 1044 | 3- 5.10 [7/64]   |
| 565 | 1-10.24 [1/4]    | 645 | 2- 1.39 [25/64]  | 725 | 2- 4.54 [35/64]  | 805 | 2- 7.69 [11/16]  | 885 | 2-10.84 [27/32]  | 965  | 3- 1.99 [63/64]  | 1045 | 3- 5.14 [9/64]   |
| 566 | 1-10.28 [9/32]   | 646 | 2- 1.43 [7/16]   | 726 | 2- 4.58 [37/64]  | 806 | 2- 7.73 [47/64]  | 886 | 2-10.88 [7/8]    | 966  | 3- 2.03 [1/32]   | 1046 | 3- 5.18 [3/16]   |
| 567 | 1-10.32 [21/64]  | 647 | 2- 1.47 [15/32]  | 727 | 2- 4.62 [5/8]    | 807 | 2- 7.77 [49/64]  | 887 | 2-10.92 [59/64]  | 967  | 3- 2.07 [5/64]   | 1047 | 3- 5.22 [7/32]   |
| 568 | 1-10.36 [23/64]  | 648 | 2- 1.51 [33/64]  | 728 | 2- 4.66 [21/32]  | 808 | 2- 7.81 [13/16]  | 888 | 2-10.96 [61/64]  | 968  | 3- 2.11 [7/64]   | 1048 | 3- 5.26 [17/64]  |
| 569 | 1-10.40 [13/32]  | 649 | 2- 1.55 [35/64]  | 729 | 2- 4.70 [45/64]  | 809 | 2- 7.85 [27/32]  | 889 | 2-11.00          | 969  | 3- 2.15 [5/32]   | 1049 | 3- 5.30 [19/64]  |
| 570 | 1-10.44 [7/16]   | 650 | 2- 1.59 [19/32]  | 730 | 2- 4.74 [47/64]  | 810 | 2- 7.89 [57/64]  | 890 | 2-11.04 [3/64]   | 970  | 3- 2.19 [3/16]   | 1050 | 3- 5.34 [11/32]  |
| 571 | 1-10.48 [31/64]  | 651 | 2- 1.63 [5/8]    | 731 | 2- 4.78 [25/32]  | 811 | 2- 7.93 [59/64]  | 891 | 2-11.08 [5/64]   | 971  | 3- 2.23 [15/64]  | 1051 | 3- 5.38 [3/8]    |
| 572 | 1-10.52 [33/64]  | 652 | 2- 1.67 [43/64]  | 732 | 2- 4.82 [13/16]  | 812 | 2- 7.97 [31/32]  | 892 | 2-11.12 [1/8]    | 972  | 3- 2.27 [17/64]  | 1052 | 3- 5.42 [27/64]  |
| 573 | 1-10.56 [9/16]   | 653 | 2- 1.71 [45/64]  | 733 | 2- 4.86 [55/64]  | 813 | 2- 8.01 [1/64]   | 893 | 2-11.16 [5/32]   | 973  | 3- 2.31 [5/16]   | 1053 | 3- 5.46 [29/64]  |
| 574 | 1-10.60 [19/32]  | 654 | 2- 1.75 [3/4]    | 734 | 2- 4.90 [57/64]  | 814 | 2- 8.05 [3/64]   | 894 | 2-11.20 [13/64]  | 974  | 3- 2.35 [11/32]  | 1054 | 3- 5.50 [1/2]    |
| 575 | 1-10.64 [41/64]  | 655 | 2- 1.79 [25/32]  | 735 | 2- 4.94 [15/16]  | 815 | 2- 8.09 [3/32]   | 895 | 2-11.24 [15/64]  | 975  | 3- 2.39 [25/64]  | 1055 | 3- 5.54 [17/32]  |
| 576 | 1-10.68 [43/64]  | 656 | 2- 1.83 [53/64]  | 736 | 2- 4.98 [31/32]  | 816 | 2- 8.13 [1/8]    | 896 | 2-11.28 [9/32]   | 976  | 3- 2.43 [27/64]  | 1056 | 3- 5.57 [37/64]  |
| 577 | 1-10.72 [23/32]  | 657 | 2- 1.87 [55/64]  | 737 | 2- 5.02 [1/64]   | 817 | 2- 8.17 [11/64]  | 897 | 2-11.31 [5/16]   | 977  | 3- 2.46 [15/32]  | 1057 | 3- 5.61 [39/64]  |
| 578 | 1-10.76 [3/4]    | 658 | 2- 1.91 [29/32]  | 738 | 2- 5.06 [1/16]   | 818 | 2- 8.20 [13/64]  | 898 | 2-11.35 [23/64]  | 978  | 3- 2.50 [1/2]    | 1058 | 3- 5.65 [21/32]  |
| 579 | 1-10.80 [51/64]  | 659 | 2- 1.94 [15/16]  | 739 | 2- 5.09 [3/32]   | 819 | 2- 8.24 [1/4]    | 899 | 2-11.39 [25/64]  | 979  | 3- 2.54 [35/64]  | 1059 | 3- 5.69 [11/16]  |
| 580 | 1-10.83 [53/64]  | 660 | 2- 1.98 [63/64]  | 740 | 2- 5.13 [9/64]   | 820 | 2- 8.28 [9/32]   | 900 | 2-11.43 [7/16]   | 980  | 3- 2.58 [37/64]  | 1060 | 3- 5.73 [47/64]  |
| 581 | 1-10.87 [7/8]    | 661 | 2- 2.02 [1/32]   | 741 | 2- 5.17 [11/64]  | 821 | 2- 8.32 [21/64]  | 901 | 2-11.47 [15/32]  | 981  | 3- 2.62 [5/8]    | 1061 | 3- 5.77 [49/64]  |
| 582 | 1-10.91 [29/32]  | 662 | 2- 2.06 [1/16]   | 742 | 2- 5.21 [7/32]   | 822 | 2- 8.36 [23/64]  | 902 | 2-11.51 [33/64]  | 982  | 3- 2.66 [21/32]  | 1062 | 3- 5.81 [13/16]  |
| 583 | 1-10.95 [61/64]  | 663 | 2- 2.10 [7/64]   | 743 | 2- 5.25 [1/4]    | 823 | 2- 8.40 [13/32]  | 903 | 2-11.55 [35/64]  | 983  | 3- 2.70 [45/64]  | 1063 | 3- 5.85 [27/32]  |
| 584 | 1-10.99 [63/64]  | 664 | 2- 2.14 [9/64]   | 744 | 2- 5.29 [19/64]  | 824 | 2- 8.44 [7/16]   | 904 | 2-11.59 [19/32]  | 984  | 3- 2.74 [47/64]  | 1064 | 3- 5.89 [57/64]  |
| 585 | 1-11.03 [1/32]   | 665 | 2- 2.18 [3/16]   | 745 | 2- 5.33 [21/64]  | 825 | 2- 8.48 [31/64]  | 905 | 2-11.63 [5/8]    | 985  | 3- 2.78 [25/32]  | 1065 | 3- 5.93 [59/64]  |
| 586 | 1-11.07 [5/64]   | 666 | 2- 2.22 [7/32]   | 746 | 2- 5.37 [3/8]    | 826 | 2- 8.52 [33/64]  | 906 | 2-11.67 [43/64]  | 986  | 3- 2.82 [13/16]  | 1066 | 3- 5.97 [31/64]  |
| 587 | 1-11.11 [7/64]   | 667 | 2- 2.26 [17/64]  | 747 | 2- 5.41 [13/32]  | 827 | 2- 8.56 [9/16]   | 907 | 2-11.71 [45/64]  | 987  | 3- 2.86 [55/64]  | 1067 | 3- 6.01 [1/64]   |
| 588 | 1-11.15 [5/32]   | 668 | 2- 2.30 [19/64]  | 748 | 2- 5.45 [29/64]  | 828 | 2- 8.60 [19/32]  | 908 | 2-11.75 [3/4]    | 988  | 3- 2.90 [57/64]  | 1068 | 3- 6.05 [3/64]   |
| 589 | 1-11.19 [3/16]   | 669 | 2- 2.34 [11/32]  | 749 | 2- 5.49 [31/64]  | 829 | 2- 8.64 [41/64]  | 909 | 2-11.79 [25/32]  | 989  | 3- 2.94 [15/16]  | 1069 | 3- 6.09 [3/8]    |
| 590 | 1-11.23 [15/64]  | 670 | 2- 2.38 [3/8]    | 750 | 2- 5.53 [17/32]  | 830 | 2- 8.68 [43/64]  | 910 | 2-11.83 [53/64]  | 990  | 3- 2.98 [31/32]  | 1070 | 3- 6.13 [1/2]    |
| 591 | 1-11.27 [17/64]  | 671 | 2- 2.42 [27/64]  | 751 | 2- 5.57 [9/16]   | 831 | 2- 8.72 [23/32]  | 911 | 2-11.87 [55/64]  | 991  | 3- 3.02 [1/64]   | 1071 | 3- 6.17 [11/64]  |
| 592 | 1-11.31 [5/16]   | 672 | 2- 2.46 [29/64]  | 752 | 2- 5.61 [39/64]  | 832 | 2- 8.76 [3/4]    | 912 | 2-11.91 [29/32]  | 992  | 3- 3.06 [1/16]   | 1072 | 3- 6.20 [13/64]  |
| 593 | 1-11.35 [11/32]  | 673 | 2- 2.50 [1/2]    | 753 | 2- 5.65 [41/64]  | 833 | 2- 8.80 [51/64]  | 913 | 2-11.94 [15/16]  | 993  | 3- 3.09 [3/32]   | 1073 | 3- 6.24 [1/4]    |
| 594 | 1-11.39 [25/64]  | 674 | 2- 2.54 [17/32]  | 754 | 2- 5.69 [11/16]  | 834 | 2- 8.83 [53/64]  | 914 | 2-11.98 [63/64]  | 994  | 3- 3.13 [9/64]   | 1074 | 3- 6.28 [9/32]   |
| 595 | 1-11.43 [27/64]  | 675 | 2- 2.57 [37/64]  | 755 | 2- 5.72 [23/32]  | 835 | 2- 8.87 [7/8]    | 915 | 3- 0.02 [1/32]   | 995  | 3- 3.17 [11/64]  | 1075 | 3- 6.32 [21/64]  |
| 596 | 1-11.46 [15/32]  | 676 | 2- 2.61 [39/64]  | 756 | 2- 5.76 [49/64]  | 836 | 2- 8.91 [29/32]  | 916 | 3- 0.06 [1/16]   | 996  | 3- 3.21 [7/32]   | 1076 | 3- 6.36 [23/64]  |
| 597 | 1-11.50 [1/2]    | 677 | 2- 2.65 [21/32]  | 757 | 2- 5.80 [51/64]  | 837 | 2- 8.95 [61/64]  | 917 | 3- 0.10 [7/64]   | 997  | 3- 3.25 [1/4]    | 1077 | 3- 6.40 [13/32]  |
| 598 | 1-11.54 [35/64]  | 678 | 2- 2.69 [11/16]  | 758 | 2- 5.84 [27/32]  | 838 | 2- 8.99 [63/64]  | 918 | 3- 0.14 [9/64]   | 998  | 3- 3.29 [19/64]  | 1078 | 3- 6.44 [7/16]   |
| 599 | 1-11.58 [37/64]  | 679 | 2- 2.73 [47/64]  | 759 | 2- 5.88 [7/8]    | 839 | 2- 9.03 [1/32]   | 919 | 3- 0.18 [3/16]   | 999  | 3- 3.33 [21/64]  | 1079 | 3- 6.48 [31/64]  |
| 600 | 1-11.62 [5/8]    | 680 | 2- 2.77 [49/64]  | 760 | 2- 5.92 [59/64]  | 840 | 2- 9.07 [5/64]   | 920 | 3- 0.22 [7/32]   | 1000 | 3- 3.37 [3/8]    | 1080 | 3- 6.52 [33/64]  |
| 601 | 1-11.66 [21/32]  | 681 | 2- 2.81 [13/16]  | 761 | 2- 5.96 [61/64]  | 841 | 2- 9.11 [7/64]   | 921 | 3- 0.26 [17/64]  | 1001 | 3- 3.41 [13/32]  | 1081 | 3- 6.56 [9/16]   |
| 602 | 1-11.70 [45/64]  | 682 | 2- 2.85 [27/32]  | 762 | 2- 6.00          | 842 | 2- 9.15 [5/32]   | 922 | 3- 0.30 [19/64]  | 1002 | 3- 3.45 [29/64]  | 1082 | 3- 6.60 [19/32]  |
| 603 | 1-11.74 [47/64]  | 683 | 2- 2.89 [57/64]  | 763 | 2- 6.04 [3/64]   | 843 | 2- 9.19 [31/64]  | 923 | 3- 0.34 [11/32]  | 1003 | 3- 3.49 [31/64]  | 1083 | 3- 6.64 [41/64]  |
| 604 | 1-11.78 [25/32]  | 684 | 2- 2.93 [59/64]  | 764 | 2- 6.08 [5/64]   | 844 | 2- 9.23 [15/64]  | 924 | 3- 0.38 [3/8]    | 1004 | 3- 3.53 [17/32]  | 1084 | 3- 6.68 [43/64]  |
| 605 | 1-11.82 [13/16]  | 685 | 2- 2.97 [31/32]  | 765 | 2- 6.12 [1/8]    | 845 | 2- 9.27 [17/64]  | 925 | 3- 0.42 [27/64]  | 1005 | 3- 3.57 [9/16]   | 1085 | 3- 6.72 [23/32]  |
| 606 | 1-11.86 [55/64]  | 686 | 2- 3.01 [1/64]   | 766 | 2- 6.16 [5/32]   | 846 | 2- 9.31 [5/16]   | 926 | 3- 0.46 [29/64]  | 1006 | 3- 3.61 [39/64]  | 1086 | 3- 6.76 [3/4]    |
| 607 | 1-11.90 [57/64]  | 687 | 2- 3.05 [3/64]   | 767 | 2- 6.20 [13/64]  | 847 | 2- 9.35 [11/32]  | 927 | 3- 0.50 [1/2]    | 1007 | 3- 3.65 [41/64]  | 1087 | 3- 6.80 [51/64]  |
| 608 | 1-11.94 [15/16]  | 688 | 2- 3.09 [3/32]   | 768 | 2- 6.24 [15/64]  | 848 | 2- 9.39 [25/64]  | 928 | 3- 0.54 [17/32]  | 1008 | 3- 3.69 [11/16]  | 1088 | 3- 6.83 [53/64]  |
| 609 | 1-11.98 [31/32]  | 689 | 2- 3.13 [1/8]    | 769 | 2- 6.28 [9/32]   | 849 | 2- 9.43 [27/64]  | 929 | 3- 0.57 [37/64]  | 1009 | 3- 3.72 [23/32]  | 1089 | 3- 6.87 [7/8]    |
| 610 | 2- 0.02 [1/64]   | 690 | 2- 3.17 [11/64]  | 770 | 2- 6.31 [5/16]   | 850 | 2- 9.46 [15/32]  | 930 | 3- 0.61 [39/64]  | 1010 | 3- 3.76 [49/64]  | 1090 | 3- 6.91 [29/32]  |
| 611 | 2- 0.06 [1/16]   | 691 | 2- 3.20 [13/64]  | 771 | 2- 6.35 [23/64]  | 851 | 2- 9.50 [1/2]    | 931 | 3- 0.65 [21/32]  | 1011 | 3- 3.80 [51/64]  | 1091 | 3- 6.95 [61/64]  |
| 612 | 2- 0.09 [3/32]   | 692 | 2- 3.24 [1/4]    | 772 | 2- 6.39 [25/64]  | 852 | 2- 9.54 [35/64]  | 932 | 3- 0.69 [11/16]  | 1012 | 3- 3.84 [27/32]  | 1092 | 3- 6.99 [63/64]  |
| 613 | 2- 0.13 [9/64]   | 693 | 2- 3.28 [9/32]   | 773 | 2- 6.43 [7/16]   | 853 | 2- 9.58 [37/64]  | 933 | 3- 0.73 [47/64]  | 1013 | 3- 3.88 [7/8]    | 1093 | 3- 7.03 [1/32]   |
| 614 | 2- 0.17 [11/64]  | 694 | 2- 3.32 [21/64]  | 774 | 2- 6.47 [15/32]  | 854 | 2- 9.62 [5/8]    | 934 | 3- 0.77 [49/64]  | 1014 | 3- 3.92 [59/64]  | 1094 | 3- 7.07 [5/64]   |
| 615 | 2- 0.21 [7/32]   | 695 | 2- 3.36 [23/64]  | 775 | 2- 6.51 [33/64]  | 855 | 2- 9.66 [21/32]  | 935 | 3- 0.81 [13/16]  | 1015 | 3- 3.96 [61/64]  | 1095 | 3- 7.11 [7/64]   |
| 616 | 2- 0.25 [1/4]    | 696 | 2- 3.40 [13/32]  | 776 | 2- 6.55 [35/64]  | 856 | 2- 9.70 [45/64]  | 936 | 3- 0.85 [27/32]  | 1016 | 3- 4.00          | 1096 | 3- 7.15 [5/32]   |
| 617 | 2- 0.29 [19/64]  | 697 | 2- 3.44 [7/16]   | 777 | 2- 6.59 [19/32]  | 857 | 2- 9.74 [47/64]  | 937 | 3- 0.89 [57/64]  | 1017 | 3- 4.04 [3/64]   | 1097 | 3- 7.19 [3/16]   |
| 618 | 2- 0.33 [21/64]  | 698 | 2- 3.48 [31/64]  | 778 | 2- 6.63 [5/8]    | 858 | 2- 9.78 [25/32]  | 938 | 3- 0.93 [59/64]  | 1018 | 3- 4.08 [5/64]   | 1098 | 3- 7.23 [15/64]  |
| 619 | 2- 0.37 [3/8]    | 699 | 2- 3.52 [33/64]  | 779 | 2- 6.67 [43/64]  | 859 | 2- 9.82 [13/16]  | 939 | 3- 0.97 [31/32]  | 1019 | 3- 4.12 [1/8]    | 1099 | 3- 7.27 [17/64]  |
| 620 | 2- 0.41 [13/32]  | 700 | 2- 3.56 [9/16]   | 780 | 2- 6.71 [45/64]  | 860 | 2- 9.86 [55/64]  | 940 | 3- 1.01 [1/64]   | 1020 | 3- 4.16 [5/32]   | 1100 | 3- 7.31 [5/16]   |
| 621 | 2- 0.45 [29/64]  | 701 | 2- 3.60 [19/32]  | 781 | 2- 6.75 [3/4]    | 861 | 2- 9.90 [57/64]  | 941 | 3- 1.05 [3/64]   | 1021 | 3- 4.20 [13/64]  | 1101 | 3- 7.35 [11/32]  |
| 622 | 2- 0.49 [31/64]  | 702 | 2- 3.64 [41/64]  | 782 | 2- 6.79 [25/32]  | 862 | 2- 9.94 [15/16]  | 942 | 3- 1.09 [3/32]   | 1022 | 3- 4.24 [15/64]  | 1102 | 3- 7.39 [25/64]  |
| 623 | 2- 0.53 [17/32]  | 703 | 2- 3.68 [43/64]  | 783 | 2- 6.83 [53/64]  | 863 | 2- 9.98 [31/32]  | 943 | 3- 1.13 [1/8]    | 1023 | 3- 4.28 [9/32]   | 1103 | 3- 7.43 [27/64]  |
| 624 | 2- 0.57 [9/16]   | 704 | 2- 3.72 [23/32]  | 784 | 2- 6.87 [55/64]  | 864 | 2-10.02 [1/64]   | 944 | 3- 1.17 [11/64]  | 1024 | 3- 4.31 [5/16]   | 1104 | 3- 7.46 [15/32]  |
| 625 | 2- 0.61 [39/64]  | 705 | 2- 3.76 [3/4]    | 785 | 2- 6.91 [29/32]  | 865 | 2-10.06 [1/16]   | 945 | 3- 1.20 [13/64]  | 1025 | 3- 4.35 [23/64]  | 1105 | 3- 7.50 [1/2]    |
| 626 | 2- 0.65 [41/64]  | 706 | 2- 3.80 [51/64]  | 786 | 2- 6.94 [15/16]  | 866 | 2-10.09 [3/32]   | 946 | 3- 1.24 [1/4]    |      |                  |      |                  |

# MILLIMETERS CONVERTED TO FEET AND INCHES

# TABLES M-3

| mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) |
|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|
| 1121 | 3- 8.13 [9/64]   | 1201 | 3-11.28 [9/32]   | 1281 | 4- 2.43 [7/16]   | 1361 | 4- 5.58 [37/64]  | 1441 | 4- 8.73 [47/64]  | 1521 | 4-11.88 [7/8]    | 1601 | 5- 3.03 [1/32]   |
| 1122 | 3- 8.17 [11/64]  | 1202 | 3-11.32 [21/64]  | 1282 | 4- 2.47 [15/32]  | 1362 | 4- 5.62 [5/8]    | 1442 | 4- 8.77 [49/64]  | 1522 | 4-11.92 [59/64]  | 1602 | 5- 3.07 [5/64]   |
| 1123 | 3- 8.21 [7/32]   | 1203 | 3-11.36 [23/64]  | 1283 | 4- 2.51 [33/64]  | 1363 | 4- 5.66 [21/32]  | 1443 | 4- 8.81 [13/16]  | 1523 | 4-11.96 [61/64]  | 1603 | 5- 3.11 [7/64]   |
| 1124 | 3- 8.25 [1/4]    | 1204 | 3-11.40 [13/32]  | 1284 | 4- 2.55 [35/64]  | 1364 | 4- 5.70 [45/64]  | 1444 | 4- 8.85 [27/32]  | 1524 | 5- 0.00          | 1604 | 5- 3.15 [5/32]   |
| 1125 | 3- 8.29 [19/64]  | 1205 | 3-11.44 [7/16]   | 1285 | 4- 2.59 [19/32]  | 1365 | 4- 5.74 [47/64]  | 1445 | 4- 8.89 [57/64]  | 1525 | 5- 0.04 [3/64]   | 1605 | 5- 3.19 [3/16]   |
| 1126 | 3- 8.33 [21/64]  | 1206 | 3-11.48 [31/64]  | 1286 | 4- 2.63 [5/8]    | 1366 | 4- 5.78 [25/32]  | 1446 | 4- 8.93 [59/64]  | 1526 | 5- 0.08 [5/64]   | 1606 | 5- 3.23 [15/64]  |
| 1127 | 3- 8.37 [3/8]    | 1207 | 3-11.52 [33/64]  | 1287 | 4- 2.67 [43/64]  | 1367 | 4- 5.82 [13/16]  | 1447 | 4- 8.97 [31/32]  | 1527 | 5- 0.12 [1/8]    | 1607 | 5- 3.27 [17/64]  |
| 1128 | 3- 8.41 [13/32]  | 1208 | 3-11.56 [9/16]   | 1288 | 4- 2.71 [45/64]  | 1368 | 4- 5.86 [55/64]  | 1448 | 4- 9.01 [1/64]   | 1528 | 5- 0.16 [5/32]   | 1608 | 5- 3.31 [5/16]   |
| 1129 | 3- 8.45 [29/64]  | 1209 | 3-11.60 [19/32]  | 1289 | 4- 2.75 [3/4]    | 1369 | 4- 5.90 [57/64]  | 1449 | 4- 9.05 [3/64]   | 1529 | 5- 0.20 [13/64]  | 1609 | 5- 3.35 [11/32]  |
| 1130 | 3- 8.49 [31/64]  | 1210 | 3-11.64 [41/64]  | 1290 | 4- 2.79 [25/32]  | 1370 | 4- 5.94 [15/16]  | 1450 | 4- 9.09 [3/32]   | 1530 | 5- 0.24 [15/64]  | 1610 | 5- 3.39 [25/64]  |
| 1131 | 3- 8.53 [17/32]  | 1211 | 3-11.68 [43/64]  | 1291 | 4- 2.83 [53/64]  | 1371 | 4- 5.98 [31/32]  | 1451 | 4- 9.13 [1/8]    | 1531 | 5- 0.28 [9/32]   | 1611 | 5- 3.43 [27/64]  |
| 1132 | 3- 8.57 [9/16]   | 1212 | 3-11.72 [23/32]  | 1292 | 4- 2.87 [55/64]  | 1372 | 4- 6.02 [1/64]   | 1452 | 4- 9.17 [11/64]  | 1532 | 5- 0.31 [5/16]   | 1612 | 5- 3.46 [15/32]  |
| 1133 | 3- 8.61 [39/64]  | 1213 | 3-11.76 [3/4]    | 1293 | 4- 2.91 [29/32]  | 1373 | 4- 6.06 [1/16]   | 1453 | 4- 9.20 [13/64]  | 1533 | 5- 0.35 [23/64]  | 1613 | 5- 3.50 [1/2]    |
| 1134 | 3- 8.65 [41/64]  | 1214 | 3-11.80 [51/64]  | 1294 | 4- 2.94 [15/16]  | 1374 | 4- 6.09 [3/32]   | 1454 | 4- 9.24 [1/4]    | 1534 | 5- 0.39 [25/64]  | 1614 | 5- 3.54 [35/64]  |
| 1135 | 3- 8.69 [11/16]  | 1215 | 3-11.83 [53/64]  | 1295 | 4- 2.98 [63/64]  | 1375 | 4- 6.13 [9/64]   | 1455 | 4- 9.28 [9/32]   | 1535 | 5- 0.43 [7/16]   | 1615 | 5- 3.58 [37/64]  |
| 1136 | 3- 8.72 [23/32]  | 1216 | 3-11.87 [7/8]    | 1296 | 4- 3.02 [1/32]   | 1376 | 4- 6.17 [11/64]  | 1456 | 4- 9.32 [21/64]  | 1536 | 5- 0.47 [15/32]  | 1616 | 5- 3.62 [5/8]    |
| 1137 | 3- 8.76 [49/64]  | 1217 | 3-11.91 [29/32]  | 1297 | 4- 3.06 [1/16]   | 1377 | 4- 6.21 [7/32]   | 1457 | 4- 9.36 [23/64]  | 1537 | 5- 0.51 [33/64]  | 1617 | 5- 3.66 [21/32]  |
| 1138 | 3- 8.80 [51/64]  | 1218 | 3-11.95 [61/64]  | 1298 | 4- 3.10 [7/64]   | 1378 | 4- 6.25 [1/4]    | 1458 | 4- 9.40 [13/32]  | 1538 | 5- 0.55 [35/64]  | 1618 | 5- 3.70 [45/64]  |
| 1139 | 3- 8.84 [29/64]  | 1219 | 3-11.99 [63/64]  | 1299 | 4- 3.14 [9/64]   | 1379 | 4- 6.29 [19/64]  | 1459 | 4- 9.44 [7/16]   | 1539 | 5- 0.59 [19/32]  | 1619 | 5- 3.74 [47/64]  |
| 1140 | 3- 8.88 [7/8]    | 1220 | 4- 0.03 [1/32]   | 1300 | 4- 3.18 [3/16]   | 1380 | 4- 6.33 [21/64]  | 1460 | 4- 9.48 [31/64]  | 1540 | 5- 0.63 [5/8]    | 1620 | 5- 3.78 [25/32]  |
| 1141 | 3- 8.92 [59/64]  | 1221 | 4- 0.07 [5/64]   | 1301 | 4- 3.22 [7/32]   | 1381 | 4- 6.37 [3/8]    | 1461 | 4- 9.52 [33/64]  | 1541 | 5- 0.67 [43/64]  | 1621 | 5- 3.82 [13/16]  |
| 1142 | 3- 8.96 [61/64]  | 1222 | 4- 0.11 [7/64]   | 1302 | 4- 3.26 [17/64]  | 1382 | 4- 6.41 [13/32]  | 1462 | 4- 9.56 [9/16]   | 1542 | 5- 0.71 [45/64]  | 1622 | 5- 3.86 [55/64]  |
| 1143 | 3- 9.00          | 1223 | 4- 0.15 [5/32]   | 1303 | 4- 3.30 [19/64]  | 1383 | 4- 6.45 [29/64]  | 1463 | 4- 9.60 [19/32]  | 1543 | 5- 0.75 [3/4]    | 1623 | 5- 3.90 [57/64]  |
| 1144 | 3- 9.04 [3/64]   | 1224 | 4- 0.19 [3/16]   | 1304 | 4- 3.34 [11/32]  | 1384 | 4- 6.49 [31/64]  | 1464 | 4- 9.64 [41/64]  | 1544 | 5- 0.79 [25/32]  | 1624 | 5- 3.94 [15/16]  |
| 1145 | 3- 9.08 [5/64]   | 1225 | 4- 0.23 [15/64]  | 1305 | 4- 3.38 [3/8]    | 1385 | 4- 6.53 [17/32]  | 1465 | 4- 9.68 [43/64]  | 1545 | 5- 0.83 [53/64]  | 1625 | 5- 3.98 [31/32]  |
| 1146 | 3- 9.12 [1/8]    | 1226 | 4- 0.27 [17/64]  | 1306 | 4- 3.42 [27/64]  | 1386 | 4- 6.57 [9/16]   | 1466 | 4- 9.72 [23/32]  | 1546 | 5- 0.87 [55/64]  | 1626 | 5- 4.02 [1/64]   |
| 1147 | 3- 9.16 [5/32]   | 1227 | 4- 0.31 [5/16]   | 1307 | 4- 3.46 [29/64]  | 1387 | 4- 6.61 [39/64]  | 1467 | 4- 9.76 [3/4]    | 1547 | 5- 0.91 [29/32]  | 1627 | 5- 4.06 [1/16]   |
| 1148 | 3- 9.20 [13/64]  | 1228 | 4- 0.35 [11/32]  | 1308 | 4- 3.50 [1/2]    | 1388 | 4- 6.65 [41/64]  | 1468 | 4- 9.80 [51/64]  | 1548 | 5- 0.94 [15/16]  | 1628 | 5- 4.09 [3/32]   |
| 1149 | 3- 9.24 [15/64]  | 1229 | 4- 0.39 [25/64]  | 1309 | 4- 3.54 [17/32]  | 1389 | 4- 6.69 [11/16]  | 1469 | 4- 9.83 [53/64]  | 1549 | 5- 0.98 [63/64]  | 1629 | 5- 4.13 [9/64]   |
| 1150 | 3- 9.28 [9/32]   | 1230 | 4- 0.43 [27/64]  | 1310 | 4- 3.57 [37/64]  | 1390 | 4- 6.72 [23/32]  | 1470 | 4- 9.87 [7/8]    | 1550 | 5- 1.02 [1/32]   | 1630 | 5- 4.17 [11/64]  |
| 1151 | 3- 9.31 [5/16]   | 1231 | 4- 0.46 [15/32]  | 1311 | 4- 3.61 [39/64]  | 1391 | 4- 6.76 [49/64]  | 1471 | 4- 9.91 [29/32]  | 1551 | 5- 1.06 [1/16]   | 1631 | 5- 4.21 [7/32]   |
| 1152 | 3- 9.35 [23/64]  | 1232 | 4- 0.50 [1/2]    | 1312 | 4- 3.65 [21/32]  | 1392 | 4- 6.80 [51/64]  | 1472 | 4- 9.95 [61/64]  | 1552 | 5- 1.10 [7/64]   | 1632 | 5- 4.25 [1/4]    |
| 1153 | 3- 9.39 [25/64]  | 1233 | 4- 0.54 [35/64]  | 1313 | 4- 3.69 [11/16]  | 1393 | 4- 6.84 [27/32]  | 1473 | 4- 9.99 [63/64]  | 1553 | 5- 1.14 [9/64]   | 1633 | 5- 4.29 [19/64]  |
| 1154 | 3- 9.43 [7/16]   | 1234 | 4- 0.58 [37/64]  | 1314 | 4- 3.73 [47/64]  | 1394 | 4- 6.88 [7/8]    | 1474 | 4-10.03 [1/32]   | 1554 | 5- 1.18 [3/16]   | 1634 | 5- 4.33 [21/64]  |
| 1155 | 3- 9.47 [15/32]  | 1235 | 4- 0.62 [5/8]    | 1315 | 4- 3.77 [49/64]  | 1395 | 4- 6.92 [59/64]  | 1475 | 4-10.07 [5/64]   | 1555 | 5- 1.22 [7/32]   | 1635 | 5- 4.37 [3/8]    |
| 1156 | 3- 9.51 [33/64]  | 1236 | 4- 0.66 [21/32]  | 1316 | 4- 3.81 [13/16]  | 1396 | 4- 6.96 [61/64]  | 1476 | 4-10.11 [7/64]   | 1556 | 5- 1.26 [17/64]  | 1636 | 5- 4.41 [13/32]  |
| 1157 | 3- 9.55 [35/64]  | 1237 | 4- 0.70 [45/64]  | 1317 | 4- 3.85 [27/32]  | 1397 | 4- 7.00          | 1477 | 4-10.15 [5/32]   | 1557 | 5- 1.30 [19/64]  | 1637 | 5- 4.45 [29/64]  |
| 1158 | 3- 9.59 [19/32]  | 1238 | 4- 0.74 [47/64]  | 1318 | 4- 3.89 [57/64]  | 1398 | 4- 7.04 [3/64]   | 1478 | 4-10.19 [3/16]   | 1558 | 5- 1.34 [11/32]  | 1638 | 5- 4.49 [31/64]  |
| 1159 | 3- 9.63 [5/8]    | 1239 | 4- 0.78 [25/32]  | 1319 | 4- 3.93 [59/64]  | 1399 | 4- 7.08 [5/64]   | 1479 | 4-10.23 [15/64]  | 1559 | 5- 1.38 [3/8]    | 1639 | 5- 4.53 [17/32]  |
| 1160 | 3- 9.67 [43/64]  | 1240 | 4- 0.82 [13/16]  | 1320 | 4- 3.97 [31/32]  | 1400 | 4- 7.12 [1/8]    | 1480 | 4-10.27 [17/64]  | 1560 | 5- 1.42 [27/64]  | 1640 | 5- 4.57 [9/16]   |
| 1161 | 3- 9.71 [45/64]  | 1241 | 4- 0.86 [55/64]  | 1321 | 4- 4.01 [1/64]   | 1401 | 4- 7.16 [5/32]   | 1481 | 4-10.31 [5/16]   | 1561 | 5- 1.46 [29/64]  | 1641 | 5- 4.61 [39/64]  |
| 1162 | 3- 9.75 [3/4]    | 1242 | 4- 0.90 [57/64]  | 1322 | 4- 4.05 [3/64]   | 1402 | 4- 7.20 [13/64]  | 1482 | 4-10.35 [11/32]  | 1562 | 5- 1.50 [1/2]    | 1642 | 5- 4.65 [41/64]  |
| 1163 | 3- 9.79 [25/32]  | 1243 | 4- 0.94 [15/16]  | 1323 | 4- 4.09 [3/32]   | 1403 | 4- 7.24 [15/64]  | 1483 | 4-10.39 [25/64]  | 1563 | 5- 1.54 [17/32]  | 1643 | 5- 4.69 [11/16]  |
| 1164 | 3- 9.83 [53/64]  | 1244 | 4- 0.98 [31/32]  | 1324 | 4- 4.13 [1/8]    | 1404 | 4- 7.28 [9/32]   | 1484 | 4-10.43 [27/64]  | 1564 | 5- 1.57 [37/64]  | 1644 | 5- 4.72 [23/32]  |
| 1165 | 3- 9.87 [55/64]  | 1245 | 4- 1.02 [1/64]   | 1325 | 4- 4.17 [11/64]  | 1405 | 4- 7.31 [5/16]   | 1485 | 4-10.46 [15/32]  | 1565 | 5- 1.61 [39/64]  | 1645 | 5- 4.76 [49/64]  |
| 1166 | 3- 9.91 [29/32]  | 1246 | 4- 1.06 [1/16]   | 1326 | 4- 4.20 [13/64]  | 1406 | 4- 7.35 [23/64]  | 1486 | 4-10.50 [1/2]    | 1566 | 5- 1.65 [21/32]  | 1646 | 5- 4.80 [51/64]  |
| 1167 | 3- 9.94 [15/16]  | 1247 | 4- 1.09 [3/32]   | 1327 | 4- 4.24 [1/4]    | 1407 | 4- 7.39 [25/64]  | 1487 | 4-10.54 [35/64]  | 1567 | 5- 1.69 [11/16]  | 1647 | 5- 4.84 [27/32]  |
| 1168 | 3- 9.98 [63/64]  | 1248 | 4- 1.13 [9/64]   | 1328 | 4- 4.28 [9/32]   | 1408 | 4- 7.43 [7/16]   | 1488 | 4-10.58 [37/64]  | 1568 | 5- 1.73 [47/64]  | 1648 | 5- 4.88 [7/8]    |
| 1169 | 3-10.02 [1/32]   | 1249 | 4- 1.17 [11/64]  | 1329 | 4- 4.32 [21/64]  | 1409 | 4- 7.47 [15/32]  | 1489 | 4-10.62 [5/8]    | 1569 | 5- 1.77 [49/64]  | 1649 | 5- 4.92 [59/64]  |
| 1170 | 3-10.06 [1/16]   | 1250 | 4- 1.21 [7/32]   | 1330 | 4- 4.36 [23/64]  | 1410 | 4- 7.51 [33/64]  | 1490 | 4-10.66 [21/32]  | 1570 | 5- 1.81 [13/16]  | 1650 | 5- 4.96 [61/64]  |
| 1171 | 3-10.10 [7/64]   | 1251 | 4- 1.25 [1/4]    | 1331 | 4- 4.40 [13/32]  | 1411 | 4- 7.55 [35/64]  | 1491 | 4-10.70 [45/64]  | 1571 | 5- 1.85 [27/32]  | 1651 | 5- 5.00          |
| 1172 | 3-10.14 [9/64]   | 1252 | 4- 1.29 [19/64]  | 1332 | 4- 4.44 [7/16]   | 1412 | 4- 7.59 [19/32]  | 1492 | 4-10.74 [47/64]  | 1572 | 5- 1.89 [57/64]  | 1652 | 5- 5.04 [3/64]   |
| 1173 | 3-10.18 [31/64]  | 1253 | 4- 1.33 [21/64]  | 1333 | 4- 4.48 [31/64]  | 1413 | 4- 7.63 [5/8]    | 1493 | 4-10.78 [25/32]  | 1573 | 5- 1.93 [59/64]  | 1653 | 5- 5.08 [5/64]   |
| 1174 | 3-10.22 [7/32]   | 1254 | 4- 1.37 [3/8]    | 1334 | 4- 4.52 [33/64]  | 1414 | 4- 7.67 [43/64]  | 1494 | 4-10.82 [13/16]  | 1574 | 5- 1.97 [31/32]  | 1654 | 5- 5.12 [1/8]    |
| 1175 | 3-10.26 [17/64]  | 1255 | 4- 1.41 [13/32]  | 1335 | 4- 4.56 [9/16]   | 1415 | 4- 7.71 [45/64]  | 1495 | 4-10.86 [55/64]  | 1575 | 5- 2.01 [1/64]   | 1655 | 5- 5.16 [5/32]   |
| 1176 | 3-10.30 [19/64]  | 1256 | 4- 1.45 [29/64]  | 1336 | 4- 4.60 [19/32]  | 1416 | 4- 7.75 [3/4]    | 1496 | 4-10.90 [57/64]  | 1576 | 5- 2.05 [3/64]   | 1656 | 5- 5.20 [13/64]  |
| 1177 | 3-10.34 [11/32]  | 1257 | 4- 1.49 [31/64]  | 1337 | 4- 4.64 [41/64]  | 1417 | 4- 7.79 [25/32]  | 1497 | 4-10.94 [15/16]  | 1577 | 5- 2.09 [3/32]   | 1657 | 5- 5.24 [15/64]  |
| 1178 | 3-10.38 [3/8]    | 1258 | 4- 1.53 [17/32]  | 1338 | 4- 4.68 [43/64]  | 1418 | 4- 7.83 [53/64]  | 1498 | 4-10.98 [31/32]  | 1578 | 5- 2.13 [1/8]    | 1658 | 5- 5.28 [9/32]   |
| 1179 | 3-10.42 [27/64]  | 1259 | 4- 1.57 [9/16]   | 1339 | 4- 4.72 [23/32]  | 1419 | 4- 7.87 [55/64]  | 1499 | 4-11.02 [1/64]   | 1579 | 5- 2.17 [11/64]  | 1659 | 5- 5.31 [5/16]   |
| 1180 | 3-10.46 [29/64]  | 1260 | 4- 1.61 [39/64]  | 1340 | 4- 4.76 [3/4]    | 1420 | 4- 7.91 [29/32]  | 1500 | 4-11.06 [1/16]   | 1580 | 5- 2.20 [13/64]  | 1660 | 5- 5.35 [23/64]  |
| 1181 | 3-10.50 [1/2]    | 1261 | 4- 1.65 [41/64]  | 1341 | 4- 4.80 [51/64]  | 1421 | 4- 7.94 [15/16]  | 1501 | 4-11.09 [3/32]   | 1581 | 5- 2.24 [1/4]    | 1661 | 5- 5.39 [25/64]  |
| 1182 | 3-10.54 [17/32]  | 1262 | 4- 1.69 [11/16]  | 1342 | 4- 4.83 [53/64]  | 1422 | 4- 7.98 [63/64]  | 1502 | 4-11.13 [9/64]   | 1582 | 5- 2.28 [9/32]   | 1662 | 5- 5.43 [7/16]   |
| 1183 | 3-10.57 [37/64]  | 1263 | 4- 1.72 [23/32]  | 1343 | 4- 4.87 [7/8]    | 1423 | 4- 8.02 [1/32]   | 1503 | 4-11.17 [11/64]  | 1583 | 5- 2.32 [21/64]  | 1663 | 5- 5.47 [15/32]  |
| 1184 | 3-10.61 [39/64]  | 1264 | 4- 1.76 [49/64]  | 1344 | 4- 4.91 [29/32]  | 1424 | 4- 8.06 [1/16]   | 1504 | 4-11.21 [7/32]   | 1584 | 5- 2.36 [23      |      |                  |

# MILLIMETERS CONVERTED TO FEET AND INCHES

# TABLES M-3

| mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) |
|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|
| 1681 | 5- 6.18 [3/16]   | 1761 | 5- 9.33 [21/64]  | 1841 | 6- 0.48 [31/64]  | 1921 | 6- 3.63 [5/8]    | 2001 | 6- 6.78 [25/32]  | 2081 | 6- 9.93 [59/64]  | 2161 | 7- 1.08 [5/64]   |
| 1682 | 5- 6.22 [7/32]   | 1762 | 5- 9.37 [3/8]    | 1842 | 6- 0.52 [33/64]  | 1922 | 6- 3.67 [43/64]  | 2002 | 6- 6.82 [13/16]  | 2082 | 6- 9.97 [31/32]  | 2162 | 7- 1.12 [1/8]    |
| 1683 | 5- 6.26 [17/64]  | 1763 | 5- 9.41 [13/32]  | 1843 | 6- 0.56 [9/16]   | 1923 | 6- 3.71 [45/64]  | 2003 | 6- 6.86 [55/64]  | 2083 | 6-10.01 [1/64]   | 2163 | 7- 1.16 [5/32]   |
| 1684 | 5- 6.30 [19/64]  | 1764 | 5- 9.45 [29/64]  | 1844 | 6- 0.60 [19/32]  | 1924 | 6- 3.75 [3/4]    | 2004 | 6- 6.90 [57/64]  | 2084 | 6-10.05 [3/64]   | 2164 | 7- 1.20 [13/64]  |
| 1685 | 5- 6.34 [11/32]  | 1765 | 5- 9.49 [31/64]  | 1845 | 6- 0.64 [41/64]  | 1925 | 6- 3.79 [25/32]  | 2005 | 6- 6.94 [15/16]  | 2085 | 6-10.09 [3/32]   | 2165 | 7- 1.24 [15/64]  |
| 1686 | 5- 6.38 [3/8]    | 1766 | 5- 9.53 [17/32]  | 1846 | 6- 0.68 [43/64]  | 1926 | 6- 3.83 [53/64]  | 2006 | 6- 6.98 [31/32]  | 2086 | 6-10.13 [1/8]    | 2166 | 7- 1.28 [9/32]   |
| 1687 | 5- 6.42 [27/64]  | 1767 | 5- 9.57 [9/16]   | 1847 | 6- 0.72 [23/32]  | 1927 | 6- 3.87 [55/64]  | 2007 | 6- 7.02 [1/64]   | 2087 | 6-10.17 [11/64]  | 2167 | 7- 1.31 [5/16]   |
| 1688 | 5- 6.46 [29/64]  | 1768 | 5- 9.61 [39/64]  | 1848 | 6- 0.76 [3/4]    | 1928 | 6- 3.91 [29/32]  | 2008 | 6- 7.06 [1/16]   | 2088 | 6-10.20 [13/64]  | 2168 | 7- 1.35 [23/64]  |
| 1689 | 5- 6.50 [1/2]    | 1769 | 5- 9.65 [41/64]  | 1849 | 6- 0.80 [51/64]  | 1929 | 6- 3.94 [15/16]  | 2009 | 6- 7.09 [3/32]   | 2089 | 6-10.24 [1/4]    | 2169 | 7- 1.39 [25/64]  |
| 1690 | 5- 6.54 [17/32]  | 1770 | 5- 9.69 [11/16]  | 1850 | 6- 0.83 [53/64]  | 1930 | 6- 3.98 [63/64]  | 2010 | 6- 7.13 [9/64]   | 2090 | 6-10.28 [9/32]   | 2170 | 7- 1.43 [7/16]   |
| 1691 | 5- 6.57 [37/64]  | 1771 | 5- 9.72 [23/32]  | 1851 | 6- 0.87 [7/8]    | 1931 | 6- 4.02 [1/32]   | 2011 | 6- 7.17 [11/64]  | 2091 | 6-10.32 [21/64]  | 2171 | 7- 1.47 [15/32]  |
| 1692 | 5- 6.61 [39/64]  | 1772 | 5- 9.76 [49/64]  | 1852 | 6- 0.91 [29/32]  | 1932 | 6- 4.06 [1/16]   | 2012 | 6- 7.21 [7/32]   | 2092 | 6-10.36 [23/64]  | 2172 | 7- 1.51 [33/64]  |
| 1693 | 5- 6.65 [21/32]  | 1773 | 5- 9.80 [51/64]  | 1853 | 6- 0.95 [61/64]  | 1933 | 6- 4.10 [7/64]   | 2013 | 6- 7.25 [1/4]    | 2093 | 6-10.40 [13/32]  | 2173 | 7- 1.55 [35/64]  |
| 1694 | 5- 6.69 [11/16]  | 1774 | 5- 9.84 [27/32]  | 1854 | 6- 0.99 [63/64]  | 1934 | 6- 4.14 [9/64]   | 2014 | 6- 7.29 [19/64]  | 2094 | 6-10.44 [7/16]   | 2174 | 7- 1.59 [19/32]  |
| 1695 | 5- 6.73 [47/64]  | 1775 | 5- 9.88 [7/8]    | 1855 | 6- 1.03 [1/32]   | 1935 | 6- 4.18 [3/16]   | 2015 | 6- 7.33 [21/64]  | 2095 | 6-10.48 [31/64]  | 2175 | 7- 1.63 [5/8]    |
| 1696 | 5- 6.77 [49/64]  | 1776 | 5- 9.92 [59/64]  | 1856 | 6- 1.07 [5/64]   | 1936 | 6- 4.22 [7/32]   | 2016 | 6- 7.37 [3/8]    | 2096 | 6-10.52 [33/64]  | 2176 | 7- 1.67 [43/64]  |
| 1697 | 5- 6.81 [13/16]  | 1777 | 5- 9.96 [61/64]  | 1857 | 6- 1.11 [7/64]   | 1937 | 6- 4.26 [17/64]  | 2017 | 6- 7.41 [13/32]  | 2097 | 6-10.56 [9/16]   | 2177 | 7- 1.71 [45/64]  |
| 1698 | 5- 6.85 [27/32]  | 1778 | 5-10.00          | 1858 | 6- 1.15 [5/32]   | 1938 | 6- 4.30 [19/64]  | 2018 | 6- 7.45 [29/64]  | 2098 | 6-10.60 [19/32]  | 2178 | 7- 1.75 [3/4]    |
| 1699 | 5- 6.89 [57/64]  | 1779 | 5-10.04 [3/64]   | 1859 | 6- 1.19 [31/16]  | 1939 | 6- 4.34 [11/32]  | 2019 | 6- 7.49 [31/64]  | 2099 | 6-10.64 [41/64]  | 2179 | 7- 1.79 [25/32]  |
| 1700 | 5- 6.93 [59/64]  | 1780 | 5-10.08 [5/64]   | 1860 | 6- 1.23 [15/64]  | 1940 | 6- 4.38 [3/8]    | 2020 | 6- 7.53 [17/32]  | 2100 | 6-10.68 [43/64]  | 2180 | 7- 1.83 [53/64]  |
| 1701 | 5- 6.97 [31/32]  | 1781 | 5-10.12 [1/8]    | 1861 | 6- 1.27 [17/64]  | 1941 | 6- 4.42 [27/64]  | 2021 | 6- 7.57 [9/16]   | 2101 | 6-10.72 [23/32]  | 2181 | 7- 1.87 [55/64]  |
| 1702 | 5- 7.01 [1/64]   | 1782 | 5-10.16 [5/32]   | 1862 | 6- 1.31 [51/16]  | 1942 | 6- 4.46 [29/64]  | 2022 | 6- 7.61 [39/64]  | 2102 | 6-10.76 [3/4]    | 2182 | 7- 1.91 [29/32]  |
| 1703 | 5- 7.05 [3/64]   | 1783 | 5-10.20 [13/64]  | 1863 | 6- 1.35 [11/32]  | 1943 | 6- 4.50 [1/2]    | 2023 | 6- 7.65 [41/64]  | 2103 | 6-10.80 [51/64]  | 2183 | 7- 1.94 [15/16]  |
| 1704 | 5- 7.09 [3/32]   | 1784 | 5-10.24 [15/64]  | 1864 | 6- 1.39 [25/64]  | 1944 | 6- 4.54 [17/32]  | 2024 | 6- 7.69 [11/16]  | 2104 | 6-10.83 [53/64]  | 2184 | 7- 1.98 [63/64]  |
| 1705 | 5- 7.13 [1/8]    | 1785 | 5-10.28 [9/32]   | 1865 | 6- 1.43 [27/64]  | 1945 | 6- 4.57 [37/64]  | 2025 | 6- 7.72 [23/32]  | 2105 | 6-10.87 [7/8]    | 2185 | 7- 2.02 [1/32]   |
| 1706 | 5- 7.17 [11/64]  | 1786 | 5-10.31 [51/16]  | 1866 | 6- 1.46 [15/32]  | 1946 | 6- 4.61 [39/64]  | 2026 | 6- 7.76 [49/64]  | 2106 | 6-10.91 [29/32]  | 2186 | 7- 2.06 [1/16]   |
| 1707 | 5- 7.20 [13/64]  | 1787 | 5-10.35 [23/64]  | 1867 | 6- 1.50 [1/2]    | 1947 | 6- 4.65 [21/32]  | 2027 | 6- 7.80 [51/64]  | 2107 | 6-10.95 [61/64]  | 2187 | 7- 2.10 [7/64]   |
| 1708 | 5- 7.24 [1/4]    | 1788 | 5-10.39 [25/64]  | 1868 | 6- 1.54 [35/64]  | 1948 | 6- 4.69 [11/16]  | 2028 | 6- 7.84 [27/32]  | 2108 | 6-10.99 [63/64]  | 2188 | 7- 2.14 [9/64]   |
| 1709 | 5- 7.28 [9/32]   | 1789 | 5-10.43 [7/16]   | 1869 | 6- 1.58 [37/64]  | 1949 | 6- 4.73 [47/64]  | 2029 | 6- 7.88 [7/8]    | 2109 | 6-11.03 [1/32]   | 2189 | 7- 2.18 [31/16]  |
| 1710 | 5- 7.32 [21/64]  | 1790 | 5-10.47 [15/32]  | 1870 | 6- 1.62 [5/8]    | 1950 | 6- 4.77 [49/64]  | 2030 | 6- 7.92 [59/64]  | 2110 | 6-11.07 [5/64]   | 2190 | 7- 2.22 [7/32]   |
| 1711 | 5- 7.36 [23/64]  | 1791 | 5-10.51 [33/64]  | 1871 | 6- 1.66 [21/32]  | 1951 | 6- 4.81 [13/16]  | 2031 | 6- 7.96 [61/64]  | 2111 | 6-11.11 [7/64]   | 2191 | 7- 2.26 [17/64]  |
| 1712 | 5- 7.40 [13/32]  | 1792 | 5-10.55 [35/64]  | 1872 | 6- 1.70 [45/64]  | 1952 | 6- 4.85 [27/32]  | 2032 | 6- 8.00          | 2112 | 6-11.15 [5/32]   | 2192 | 7- 2.30 [19/64]  |
| 1713 | 5- 7.44 [7/16]   | 1793 | 5-10.59 [19/32]  | 1873 | 6- 1.74 [47/64]  | 1953 | 6- 4.89 [57/64]  | 2033 | 6- 8.04 [3/64]   | 2113 | 6-11.19 [31/16]  | 2193 | 7- 2.34 [11/32]  |
| 1714 | 5- 7.48 [31/64]  | 1794 | 5-10.63 [5/8]    | 1874 | 6- 1.78 [25/32]  | 1954 | 6- 4.93 [59/64]  | 2034 | 6- 8.08 [5/64]   | 2114 | 6-11.23 [15/64]  | 2194 | 7- 2.38 [3/8]    |
| 1715 | 5- 7.52 [33/64]  | 1795 | 5-10.67 [43/64]  | 1875 | 6- 1.82 [13/16]  | 1955 | 6- 4.97 [31/32]  | 2035 | 6- 8.12 [1/8]    | 2115 | 6-11.27 [17/64]  | 2195 | 7- 2.42 [27/64]  |
| 1716 | 5- 7.56 [9/16]   | 1796 | 5-10.71 [45/64]  | 1876 | 6- 1.86 [55/64]  | 1956 | 6- 5.01 [1/64]   | 2036 | 6- 8.16 [5/32]   | 2116 | 6-11.31 [51/16]  | 2196 | 7- 2.46 [29/64]  |
| 1717 | 5- 7.60 [19/32]  | 1797 | 5-10.75 [3/4]    | 1877 | 6- 1.90 [57/64]  | 1957 | 6- 5.05 [3/64]   | 2037 | 6- 8.20 [13/64]  | 2117 | 6-11.35 [11/32]  | 2197 | 7- 2.50 [1/2]    |
| 1718 | 5- 7.64 [41/64]  | 1798 | 5-10.79 [25/32]  | 1878 | 6- 1.94 [15/16]  | 1958 | 6- 5.09 [3/32]   | 2038 | 6- 8.24 [15/64]  | 2118 | 6-11.39 [25/64]  | 2198 | 7- 2.54 [17/32]  |
| 1719 | 5- 7.68 [43/64]  | 1799 | 5-10.83 [53/64]  | 1879 | 6- 1.98 [31/32]  | 1959 | 6- 5.13 [1/8]    | 2039 | 6- 8.28 [9/32]   | 2119 | 6-11.43 [27/64]  | 2199 | 7- 2.57 [37/64]  |
| 1720 | 5- 7.72 [23/32]  | 1800 | 5-10.87 [55/64]  | 1880 | 6- 2.02 [1/64]   | 1960 | 6- 5.17 [11/64]  | 2040 | 6- 8.31 [5/16]   | 2120 | 6-11.46 [15/32]  | 2200 | 7- 2.61 [39/64]  |
| 1721 | 5- 7.76 [3/4]    | 1801 | 5-10.91 [29/32]  | 1881 | 6- 2.06 [1/16]   | 1961 | 6- 5.20 [13/64]  | 2041 | 6- 8.35 [23/64]  | 2121 | 6-11.50 [1/2]    | 2201 | 7- 2.65 [21/32]  |
| 1722 | 5- 7.80 [51/64]  | 1802 | 5-10.94 [15/16]  | 1882 | 6- 2.09 [3/32]   | 1962 | 6- 5.24 [1/4]    | 2042 | 6- 8.39 [25/64]  | 2122 | 6-11.54 [35/64]  | 2202 | 7- 2.69 [11/16]  |
| 1723 | 5- 7.83 [53/64]  | 1803 | 5-10.98 [63/64]  | 1883 | 6- 2.13 [9/64]   | 1963 | 6- 5.28 [9/32]   | 2043 | 6- 8.43 [7/16]   | 2123 | 6-11.58 [37/64]  | 2203 | 7- 2.73 [47/64]  |
| 1724 | 5- 7.87 [7/8]    | 1804 | 5-11.02 [1/32]   | 1884 | 6- 2.17 [11/64]  | 1964 | 6- 5.32 [21/64]  | 2044 | 6- 8.47 [15/32]  | 2124 | 6-11.62 [5/8]    | 2204 | 7- 2.77 [49/64]  |
| 1725 | 5- 7.91 [29/32]  | 1805 | 5-11.06 [1/16]   | 1885 | 6- 2.21 [7/32]   | 1965 | 6- 5.36 [23/64]  | 2045 | 6- 8.51 [33/64]  | 2125 | 6-11.66 [21/32]  | 2205 | 7- 2.81 [13/16]  |
| 1726 | 5- 7.95 [61/64]  | 1806 | 5-11.10 [7/64]   | 1886 | 6- 2.25 [1/4]    | 1966 | 6- 5.40 [13/32]  | 2046 | 6- 8.55 [35/64]  | 2126 | 6-11.70 [45/64]  | 2206 | 7- 2.85 [27/32]  |
| 1727 | 5- 7.99 [63/64]  | 1807 | 5-11.14 [9/64]   | 1887 | 6- 2.29 [19/64]  | 1967 | 6- 5.44 [7/16]   | 2047 | 6- 8.59 [19/32]  | 2127 | 6-11.74 [47/64]  | 2207 | 7- 2.89 [57/64]  |
| 1728 | 5- 8.03 [1/32]   | 1808 | 5-11.18 [31/64]  | 1888 | 6- 2.33 [21/64]  | 1968 | 6- 5.48 [31/64]  | 2048 | 6- 8.63 [5/8]    | 2128 | 6-11.78 [25/32]  | 2208 | 7- 2.93 [59/64]  |
| 1729 | 5- 8.07 [5/64]   | 1809 | 5-11.22 [7/32]   | 1889 | 6- 2.37 [3/8]    | 1969 | 6- 5.52 [33/64]  | 2049 | 6- 8.67 [43/64]  | 2129 | 6-11.82 [13/16]  | 2209 | 7- 2.97 [31/32]  |
| 1730 | 5- 8.11 [7/64]   | 1810 | 5-11.26 [17/64]  | 1890 | 6- 2.41 [13/32]  | 1970 | 6- 5.56 [9/16]   | 2050 | 6- 8.71 [45/64]  | 2130 | 6-11.86 [55/64]  | 2210 | 7- 3.01 [1/64]   |
| 1731 | 5- 8.15 [5/32]   | 1811 | 5-11.30 [19/64]  | 1891 | 6- 2.45 [29/64]  | 1971 | 6- 5.60 [19/32]  | 2051 | 6- 8.75 [3/4]    | 2131 | 6-11.90 [57/64]  | 2211 | 7- 3.05 [3/64]   |
| 1732 | 5- 8.19 [31/16]  | 1812 | 5-11.34 [11/32]  | 1892 | 6- 2.49 [31/64]  | 1972 | 6- 5.64 [41/64]  | 2052 | 6- 8.79 [25/32]  | 2132 | 6-11.94 [15/16]  | 2212 | 7- 3.09 [3/32]   |
| 1733 | 5- 8.23 [15/64]  | 1813 | 5-11.38 [3/8]    | 1893 | 6- 2.53 [17/32]  | 1973 | 6- 5.68 [43/64]  | 2053 | 6- 8.83 [53/64]  | 2133 | 6-11.98 [31/32]  | 2213 | 7- 3.13 [1/8]    |
| 1734 | 5- 8.27 [17/64]  | 1814 | 5-11.42 [27/64]  | 1894 | 6- 2.57 [9/16]   | 1974 | 6- 5.72 [23/32]  | 2054 | 6- 8.87 [55/64]  | 2134 | 7- 0.02 [1/64]   | 2214 | 7- 3.17 [11/64]  |
| 1735 | 5- 8.31 [5/16]   | 1815 | 5-11.46 [29/64]  | 1895 | 6- 2.61 [39/64]  | 1975 | 6- 5.76 [3/4]    | 2055 | 6- 8.91 [29/32]  | 2135 | 7- 0.06 [1/16]   | 2215 | 7- 3.20 [13/64]  |
| 1736 | 5- 8.35 [11/32]  | 1816 | 5-11.50 [1/2]    | 1896 | 6- 2.65 [41/64]  | 1976 | 6- 5.80 [51/64]  | 2056 | 6- 8.94 [15/16]  | 2136 | 7- 0.09 [3/32]   | 2216 | 7- 3.24 [1/4]    |
| 1737 | 5- 8.39 [25/64]  | 1817 | 5-11.54 [17/32]  | 1897 | 6- 2.69 [11/16]  | 1977 | 6- 5.83 [53/64]  | 2057 | 6- 8.98 [63/64]  | 2137 | 7- 0.13 [9/64]   | 2217 | 7- 3.28 [9/32]   |
| 1738 | 5- 8.43 [27/64]  | 1818 | 5-11.57 [37/64]  | 1898 | 6- 2.72 [23/32]  | 1978 | 6- 5.87 [7/8]    | 2058 | 6- 9.02 [1/32]   | 2138 | 7- 0.17 [11/64]  | 2218 | 7- 3.32 [21/64]  |
| 1739 | 5- 8.46 [15/32]  | 1819 | 5-11.61 [39/64]  | 1899 | 6- 2.76 [49/64]  | 1979 | 6- 5.91 [29/32]  | 2059 | 6- 9.06 [1/16]   | 2139 | 7- 0.21 [7/32]   | 2219 | 7- 3.36 [23/64]  |
| 1740 | 5- 8.50 [1/2]    | 1820 | 5-11.65 [21/32]  | 1900 | 6- 2.80 [51/64]  | 1980 | 6- 5.95 [61/64]  | 2060 | 6- 9.10 [7/64]   | 2140 | 7- 0.25 [1/4]    | 2220 | 7- 3.40 [13/32]  |
| 1741 | 5- 8.54 [35/64]  | 1821 | 5-11.69 [11/16]  | 1901 | 6- 2.84 [27/32]  | 1981 | 6- 5.99 [63/64]  | 2061 | 6- 9.14 [9/64]   | 2141 | 7- 0.29 [19/64]  | 2221 | 7- 3.44 [7/16]   |
| 1742 | 5- 8.58 [37/64]  | 1822 | 5-11.73 [47/64]  | 1902 | 6- 2.88 [7/8]    | 1982 | 6- 6.03 [1/32]   | 2062 | 6- 9.18 [31/16]  | 2142 | 7- 0.33 [21/64]  | 2222 | 7- 3.48 [31/64]  |
| 1743 | 5- 8.62 [5/8]    | 1823 | 5-11.77 [49/64]  | 1903 | 6- 2.92 [59/64]  | 1983 | 6- 6.07 [5/64]   | 2063 | 6- 9.22 [7/32]   | 2143 | 7- 0.37 [3/8]    | 2223 | 7- 3.52 [33/64]  |
| 1744 | 5- 8.66 [21/32]  | 1824 | 5-11.81 [13/16]  | 1904 | 6- 2.96 [61/64]  | 1984 | 6- 6.11 [7/64]   | 2064 | 6- 9.26 [17/64]  | 2    |                  |      |                  |

# MILLIMETERS CONVERTED TO FEET AND INCHES

# TABLES M-3

| mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) |
|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|
| 2241 | 7- 4.23 [15/64]  | 2321 | 7- 7.38 [3/8]    | 2401 | 7-10.53 [17/32]  | 2481 | 8- 1.68 [43/64]  | 2561 | 8- 4.83 [53/64]  | 2641 | 8- 7.98 [31/32]  | 2721 | 8-11.13 [1/8]    |
| 2242 | 7- 4.27 [17/64]  | 2322 | 7- 7.42 [27/64]  | 2402 | 7-10.57 [9/16]   | 2482 | 8- 1.72 [23/32]  | 2562 | 8- 4.87 [55/64]  | 2642 | 8- 8.02 [1/64]   | 2722 | 8-11.17 [11/64]  |
| 2243 | 7- 4.31 [5/16]   | 2323 | 7- 7.46 [29/64]  | 2403 | 7-10.61 [39/64]  | 2483 | 8- 1.76 [3/4]    | 2563 | 8- 4.91 [29/32]  | 2643 | 8- 8.06 [1/16]   | 2723 | 8-11.20 [13/64]  |
| 2244 | 7- 4.35 [11/32]  | 2324 | 7- 7.50 [1/2]    | 2404 | 7-10.65 [41/64]  | 2484 | 8- 1.80 [51/64]  | 2564 | 8- 4.94 [15/16]  | 2644 | 8- 8.09 [3/32]   | 2724 | 8-11.24 [1/4]    |
| 2245 | 7- 4.39 [25/64]  | 2325 | 7- 7.54 [17/32]  | 2405 | 7-10.69 [11/16]  | 2485 | 8- 1.83 [53/64]  | 2565 | 8- 4.98 [63/64]  | 2645 | 8- 8.13 [9/64]   | 2725 | 8-11.28 [9/32]   |
| 2246 | 7- 4.43 [27/64]  | 2326 | 7- 7.57 [37/64]  | 2406 | 7-10.72 [23/32]  | 2486 | 8- 1.87 [7/8]    | 2566 | 8- 5.02 [1/32]   | 2646 | 8- 8.17 [11/64]  | 2726 | 8-11.32 [21/64]  |
| 2247 | 7- 4.46 [15/32]  | 2327 | 7- 7.61 [39/64]  | 2407 | 7-10.76 [49/64]  | 2487 | 8- 1.91 [29/32]  | 2567 | 8- 5.06 [1/16]   | 2647 | 8- 8.21 [7/32]   | 2727 | 8-11.36 [23/64]  |
| 2248 | 7- 4.50 [1/2]    | 2328 | 7- 7.65 [21/32]  | 2408 | 7-10.80 [51/64]  | 2488 | 8- 1.95 [61/64]  | 2568 | 8- 5.10 [7/64]   | 2648 | 8- 8.25 [1/4]    | 2728 | 8-11.40 [13/32]  |
| 2249 | 7- 4.54 [35/64]  | 2329 | 7- 7.69 [11/16]  | 2409 | 7-10.84 [27/32]  | 2489 | 8- 1.99 [63/64]  | 2569 | 8- 5.14 [9/64]   | 2649 | 8- 8.29 [19/64]  | 2729 | 8-11.44 [7/16]   |
| 2250 | 7- 4.58 [37/64]  | 2330 | 7- 7.73 [47/64]  | 2410 | 7-10.88 [7/8]    | 2490 | 8- 2.03 [1/32]   | 2570 | 8- 5.18 [3/16]   | 2650 | 8- 8.33 [21/64]  | 2730 | 8-11.48 [31/64]  |
| 2251 | 7- 4.62 [5/8]    | 2331 | 7- 7.77 [49/64]  | 2411 | 7-10.92 [59/64]  | 2491 | 8- 2.07 [5/64]   | 2571 | 8- 5.22 [7/32]   | 2651 | 8- 8.37 [3/8]    | 2731 | 8-11.52 [33/64]  |
| 2252 | 7- 4.66 [21/32]  | 2332 | 7- 7.81 [13/16]  | 2412 | 7-10.96 [61/64]  | 2492 | 8- 2.11 [7/64]   | 2572 | 8- 5.26 [17/64]  | 2652 | 8- 8.41 [13/32]  | 2732 | 8-11.56 [9/16]   |
| 2253 | 7- 4.70 [45/64]  | 2333 | 7- 7.85 [27/32]  | 2413 | 7-11.00          | 2493 | 8- 2.15 [5/32]   | 2573 | 8- 5.30 [19/64]  | 2653 | 8- 8.45 [29/64]  | 2733 | 8-11.60 [19/32]  |
| 2254 | 7- 4.74 [47/64]  | 2334 | 7- 7.89 [57/64]  | 2414 | 7-11.04 [3/64]   | 2494 | 8- 2.19 [3/16]   | 2574 | 8- 5.34 [11/32]  | 2654 | 8- 8.49 [31/64]  | 2734 | 8-11.64 [41/64]  |
| 2255 | 7- 4.78 [25/32]  | 2335 | 7- 7.93 [59/64]  | 2415 | 7-11.08 [5/64]   | 2495 | 8- 2.23 [15/64]  | 2575 | 8- 5.38 [3/8]    | 2655 | 8- 8.53 [17/32]  | 2735 | 8-11.68 [43/64]  |
| 2256 | 7- 4.82 [13/16]  | 2336 | 7- 7.97 [31/32]  | 2416 | 7-11.12 [1/8]    | 2496 | 8- 2.27 [17/64]  | 2576 | 8- 5.42 [27/64]  | 2656 | 8- 8.57 [9/16]   | 2736 | 8-11.72 [23/32]  |
| 2257 | 7- 4.86 [55/64]  | 2337 | 7- 8.01 [1/64]   | 2417 | 7-11.16 [5/32]   | 2497 | 8- 2.31 [5/16]   | 2577 | 8- 5.46 [29/64]  | 2657 | 8- 8.61 [39/64]  | 2737 | 8-11.76 [3/4]    |
| 2258 | 7- 4.90 [57/64]  | 2338 | 7- 8.05 [3/64]   | 2418 | 7-11.20 [13/64]  | 2498 | 8- 2.35 [11/32]  | 2578 | 8- 5.50 [1/2]    | 2658 | 8- 8.65 [41/64]  | 2738 | 8-11.80 [51/64]  |
| 2259 | 7- 4.94 [15/16]  | 2339 | 7- 8.09 [3/32]   | 2419 | 7-11.24 [15/64]  | 2499 | 8- 2.39 [25/64]  | 2579 | 8- 5.54 [17/32]  | 2659 | 8- 8.69 [11/16]  | 2739 | 8-11.84 [53/64]  |
| 2260 | 7- 4.98 [31/32]  | 2340 | 7- 8.13 [1/8]    | 2420 | 7-11.28 [9/32]   | 2500 | 8- 2.43 [27/64]  | 2580 | 8- 5.57 [37/64]  | 2660 | 8- 8.72 [23/32]  | 2740 | 8-11.87 [7/8]    |
| 2261 | 7- 5.02 [1/64]   | 2341 | 7- 8.17 [11/64]  | 2421 | 7-11.31 [5/16]   | 2501 | 8- 2.46 [15/32]  | 2581 | 8- 5.61 [39/64]  | 2661 | 8- 8.76 [49/64]  | 2741 | 8-11.91 [29/32]  |
| 2262 | 7- 5.06 [1/16]   | 2342 | 7- 8.20 [13/64]  | 2422 | 7-11.35 [23/64]  | 2502 | 8- 2.50 [1/2]    | 2582 | 8- 5.65 [21/32]  | 2662 | 8- 8.80 [51/64]  | 2742 | 8-11.95 [61/64]  |
| 2263 | 7- 5.09 [3/32]   | 2343 | 7- 8.24 [1/4]    | 2423 | 7-11.39 [25/64]  | 2503 | 8- 2.54 [35/64]  | 2583 | 8- 5.69 [11/16]  | 2663 | 8- 8.84 [27/32]  | 2743 | 8-11.99 [63/64]  |
| 2264 | 7- 5.13 [9/64]   | 2344 | 7- 8.28 [9/32]   | 2424 | 7-11.43 [7/16]   | 2504 | 8- 2.58 [37/64]  | 2584 | 8- 5.73 [47/64]  | 2664 | 8- 8.88 [7/8]    | 2744 | 9- 0.03 [1/32]   |
| 2265 | 7- 5.17 [11/64]  | 2345 | 7- 8.32 [21/64]  | 2425 | 7-11.47 [15/32]  | 2505 | 8- 2.62 [5/8]    | 2585 | 8- 5.77 [49/64]  | 2665 | 8- 8.92 [59/64]  | 2745 | 9- 0.07 [5/64]   |
| 2266 | 7- 5.21 [7/32]   | 2346 | 7- 8.36 [23/64]  | 2426 | 7-11.51 [33/64]  | 2506 | 8- 2.66 [21/32]  | 2586 | 8- 5.81 [13/16]  | 2666 | 8- 8.96 [61/64]  | 2746 | 9- 0.11 [7/64]   |
| 2267 | 7- 5.25 [1/4]    | 2347 | 7- 8.40 [13/32]  | 2427 | 7-11.55 [35/64]  | 2507 | 8- 2.70 [45/64]  | 2587 | 8- 5.85 [27/32]  | 2667 | 8- 9.00          | 2747 | 9- 0.15 [5/32]   |
| 2268 | 7- 5.29 [19/64]  | 2348 | 7- 8.44 [7/16]   | 2428 | 7-11.59 [19/32]  | 2508 | 8- 2.74 [47/64]  | 2588 | 8- 5.89 [57/64]  | 2668 | 8- 9.04 [3/64]   | 2748 | 9- 0.19 [3/16]   |
| 2269 | 7- 5.33 [21/64]  | 2349 | 7- 8.48 [31/64]  | 2429 | 7-11.63 [5/8]    | 2509 | 8- 2.78 [25/32]  | 2589 | 8- 5.93 [59/64]  | 2669 | 8- 9.08 [5/64]   | 2749 | 9- 0.23 [15/64]  |
| 2270 | 7- 5.37 [3/8]    | 2350 | 7- 8.52 [33/64]  | 2430 | 7-11.67 [43/64]  | 2510 | 8- 2.82 [13/16]  | 2590 | 8- 5.97 [31/32]  | 2670 | 8- 9.12 [1/8]    | 2750 | 9- 0.27 [17/64]  |
| 2271 | 7- 5.41 [13/32]  | 2351 | 7- 8.56 [9/16]   | 2431 | 7-11.71 [45/64]  | 2511 | 8- 2.86 [55/64]  | 2591 | 8- 6.01 [1/64]   | 2671 | 8- 9.16 [5/32]   | 2751 | 9- 0.31 [5/16]   |
| 2272 | 7- 5.45 [29/64]  | 2352 | 7- 8.60 [19/32]  | 2432 | 7-11.75 [3/4]    | 2512 | 8- 2.90 [57/64]  | 2592 | 8- 6.05 [3/64]   | 2672 | 8- 9.20 [13/64]  | 2752 | 9- 0.35 [11/32]  |
| 2273 | 7- 5.49 [31/64]  | 2353 | 7- 8.64 [41/64]  | 2433 | 7-11.79 [25/32]  | 2513 | 8- 2.94 [15/16]  | 2593 | 8- 6.09 [3/32]   | 2673 | 8- 9.24 [15/64]  | 2753 | 9- 0.39 [25/64]  |
| 2274 | 7- 5.53 [17/32]  | 2354 | 7- 8.68 [43/64]  | 2434 | 7-11.83 [53/64]  | 2514 | 8- 2.98 [31/32]  | 2594 | 8- 6.13 [1/8]    | 2674 | 8- 9.28 [9/32]   | 2754 | 9- 0.43 [27/64]  |
| 2275 | 7- 5.57 [9/16]   | 2355 | 7- 8.72 [23/32]  | 2435 | 7-11.87 [55/64]  | 2515 | 8- 3.02 [1/64]   | 2595 | 8- 6.17 [11/64]  | 2675 | 8- 9.31 [5/16]   | 2755 | 9- 0.46 [15/32]  |
| 2276 | 7- 5.61 [39/64]  | 2356 | 7- 8.76 [3/4]    | 2436 | 7-11.91 [29/32]  | 2516 | 8- 3.06 [1/16]   | 2596 | 8- 6.20 [13/64]  | 2676 | 8- 9.35 [23/64]  | 2756 | 9- 0.50 [1/2]    |
| 2277 | 7- 5.65 [41/64]  | 2357 | 7- 8.80 [51/64]  | 2437 | 7-11.94 [15/16]  | 2517 | 8- 3.09 [3/32]   | 2597 | 8- 6.24 [1/4]    | 2677 | 8- 9.39 [25/64]  | 2757 | 9- 0.54 [35/64]  |
| 2278 | 7- 5.69 [11/16]  | 2358 | 7- 8.83 [53/64]  | 2438 | 7-11.98 [63/64]  | 2518 | 8- 3.13 [9/64]   | 2598 | 8- 6.28 [9/32]   | 2678 | 8- 9.43 [7/16]   | 2758 | 9- 0.58 [37/64]  |
| 2279 | 7- 5.72 [23/32]  | 2359 | 7- 8.87 [7/8]    | 2439 | 8- 0.02 [1/32]   | 2519 | 8- 3.17 [11/64]  | 2599 | 8- 6.32 [21/64]  | 2679 | 8- 9.47 [15/32]  | 2759 | 9- 0.62 [5/8]    |
| 2280 | 7- 5.76 [49/64]  | 2360 | 7- 8.91 [29/32]  | 2440 | 8- 0.06 [1/16]   | 2520 | 8- 3.21 [7/32]   | 2600 | 8- 6.36 [23/64]  | 2680 | 8- 9.51 [33/64]  | 2760 | 9- 0.66 [21/32]  |
| 2281 | 7- 5.80 [51/64]  | 2361 | 7- 8.95 [61/64]  | 2441 | 8- 0.10 [7/64]   | 2521 | 8- 3.25 [1/4]    | 2601 | 8- 6.40 [13/32]  | 2681 | 8- 9.55 [35/64]  | 2761 | 9- 0.70 [45/64]  |
| 2282 | 7- 5.84 [27/32]  | 2362 | 7- 8.99 [63/64]  | 2442 | 8- 0.14 [9/64]   | 2522 | 8- 3.29 [19/64]  | 2602 | 8- 6.44 [7/16]   | 2682 | 8- 9.59 [19/32]  | 2762 | 9- 0.74 [47/64]  |
| 2283 | 7- 5.88 [7/8]    | 2363 | 7- 9.03 [1/32]   | 2443 | 8- 0.18 [3/16]   | 2523 | 8- 3.33 [21/64]  | 2603 | 8- 6.48 [31/64]  | 2683 | 8- 9.63 [5/8]    | 2763 | 9- 0.78 [25/32]  |
| 2284 | 7- 5.92 [59/64]  | 2364 | 7- 9.07 [5/64]   | 2444 | 8- 0.22 [7/32]   | 2524 | 8- 3.37 [3/8]    | 2604 | 8- 6.52 [33/64]  | 2684 | 8- 9.67 [43/64]  | 2764 | 9- 0.82 [13/16]  |
| 2285 | 7- 5.96 [61/64]  | 2365 | 7- 9.11 [7/64]   | 2445 | 8- 0.26 [17/64]  | 2525 | 8- 3.41 [13/32]  | 2605 | 8- 6.56 [9/16]   | 2685 | 8- 9.71 [45/64]  | 2765 | 9- 0.86 [55/64]  |
| 2286 | 6- 0.00          | 2366 | 7- 9.15 [5/32]   | 2446 | 8- 0.30 [19/64]  | 2526 | 8- 3.45 [29/64]  | 2606 | 8- 6.60 [19/32]  | 2686 | 8- 9.75 [3/4]    | 2766 | 9- 0.90 [57/64]  |
| 2287 | 7- 6.04 [3/64]   | 2367 | 7- 9.19 [3/16]   | 2447 | 8- 0.34 [11/32]  | 2527 | 8- 3.49 [31/64]  | 2607 | 8- 6.64 [41/64]  | 2687 | 8- 9.79 [25/32]  | 2767 | 9- 0.94 [15/16]  |
| 2288 | 7- 6.08 [5/64]   | 2368 | 7- 9.23 [15/64]  | 2448 | 8- 0.38 [3/8]    | 2528 | 8- 3.53 [17/32]  | 2608 | 8- 6.68 [43/64]  | 2688 | 8- 9.83 [53/64]  | 2768 | 9- 0.98 [31/32]  |
| 2289 | 7- 6.12 [1/8]    | 2369 | 7- 9.27 [17/64]  | 2449 | 8- 0.42 [27/64]  | 2529 | 8- 3.57 [9/16]   | 2609 | 8- 6.72 [23/32]  | 2689 | 8- 9.87 [55/64]  | 2769 | 9- 1.02 [1/64]   |
| 2290 | 7- 6.16 [5/32]   | 2370 | 7- 9.31 [5/16]   | 2450 | 8- 0.46 [29/64]  | 2530 | 8- 3.61 [39/64]  | 2610 | 8- 6.76 [3/4]    | 2690 | 8- 9.91 [29/32]  | 2770 | 9- 1.06 [1/16]   |
| 2291 | 7- 6.20 [13/64]  | 2371 | 7- 9.35 [11/32]  | 2451 | 8- 0.50 [1/2]    | 2531 | 8- 3.65 [41/64]  | 2611 | 8- 6.80 [51/64]  | 2691 | 8- 9.94 [15/16]  | 2771 | 9- 1.09 [3/32]   |
| 2292 | 7- 6.24 [15/64]  | 2372 | 7- 9.39 [25/64]  | 2452 | 8- 0.54 [17/32]  | 2532 | 8- 3.69 [11/16]  | 2612 | 8- 6.83 [53/64]  | 2692 | 8- 9.98 [63/64]  | 2772 | 9- 1.13 [9/64]   |
| 2293 | 7- 6.28 [9/32]   | 2373 | 7- 9.43 [27/64]  | 2453 | 8- 0.57 [37/64]  | 2533 | 8- 3.72 [23/32]  | 2613 | 8- 6.87 [7/8]    | 2693 | 8-10.02 [1/32]   | 2773 | 9- 1.17 [11/64]  |
| 2294 | 7- 6.31 [5/16]   | 2374 | 7- 9.46 [15/32]  | 2454 | 8- 0.61 [39/64]  | 2534 | 8- 3.76 [49/64]  | 2614 | 8- 6.91 [29/32]  | 2694 | 8-10.06 [1/16]   | 2774 | 9- 1.21 [7/32]   |
| 2295 | 7- 6.35 [23/64]  | 2375 | 7- 9.50 [1/2]    | 2455 | 8- 0.65 [21/32]  | 2535 | 8- 3.80 [51/64]  | 2615 | 8- 6.95 [61/64]  | 2695 | 8-10.10 [7/64]   | 2775 | 9- 1.25 [1/4]    |
| 2296 | 7- 6.39 [25/64]  | 2376 | 7- 9.54 [35/64]  | 2456 | 8- 0.69 [11/16]  | 2536 | 8- 3.84 [27/32]  | 2616 | 8- 6.99 [63/64]  | 2696 | 8-10.14 [9/64]   | 2776 | 9- 1.29 [19/64]  |
| 2297 | 7- 6.43 [7/16]   | 2377 | 7- 9.58 [37/64]  | 2457 | 8- 0.73 [47/64]  | 2537 | 8- 3.88 [7/8]    | 2617 | 8- 7.03 [1/32]   | 2697 | 8-10.18 [13/16]  | 2777 | 9- 1.33 [21/64]  |
| 2298 | 7- 6.47 [15/32]  | 2378 | 7- 9.62 [5/8]    | 2458 | 8- 0.77 [49/64]  | 2538 | 8- 3.92 [59/64]  | 2618 | 8- 7.07 [5/64]   | 2698 | 8-10.22 [7/32]   | 2778 | 9- 1.37 [3/8]    |
| 2299 | 7- 6.51 [33/64]  | 2379 | 7- 9.66 [21/32]  | 2459 | 8- 0.81 [13/16]  | 2539 | 8- 3.96 [61/64]  | 2619 | 8- 7.11 [7/64]   | 2699 | 8-10.26 [17/64]  | 2779 | 9- 1.41 [13/32]  |
| 2300 | 7- 6.55 [35/64]  | 2380 | 7- 9.70 [45/64]  | 2460 | 8- 0.85 [27/32]  | 2540 | 8- 4.00          | 2620 | 8- 7.15 [5/32]   | 2700 | 8-10.30 [19/64]  | 2780 | 9- 1.45 [29/64]  |
| 2301 | 7- 6.59 [19/32]  | 2381 | 7- 9.74 [47/64]  | 2461 | 8- 0.89 [57/64]  | 2541 | 8- 4.04 [3/64]   | 2621 | 8- 7.19 [3/16]   | 2701 | 8-10.34 [11/32]  | 2781 | 9- 1.49 [31/64]  |
| 2302 | 7- 6.63 [5/8]    | 2382 | 7- 9.78 [25/32]  | 2462 | 8- 0.93 [59/64]  | 2542 | 8- 4.08 [5/64]   | 2622 | 8- 7.23 [15/64]  | 2702 | 8-10.38 [3/8]    | 2782 | 9- 1.53 [17/32]  |
| 2303 | 7- 6.67 [43/64]  | 2383 | 7- 9.82 [13/16]  | 2463 | 8- 0.97 [31/32]  | 2543 | 8- 4.12 [1/8]    | 2623 | 8- 7.27 [17/64]  | 2703 | 8-10.42 [27/64]  | 2783 | 9- 1.57 [9/16]   |
| 2304 | 7- 6.71 [45/64]  | 2384 | 7- 9.86 [55/64]  | 2464 | 8- 1.01 [1/64]   | 2544 | 8- 4.16 [5/32]   | 2624 | 8- 7.31 [5/16]   | 2704 | 8-10.46 [2       |      |                  |

# MILLIMETERS CONVERTED TO FEET AND INCHES

# TABLES M-3

| mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) |
|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|
| 2801 | 9- 2.28 [9/32]   | 2881 | 9- 5.43 [27/64]  | 2961 | 9- 8.57 [37/64]  | 3041 | 9-11.72 [23/32]  | 3121 | 10- 2.87 [7/8]   | 3201 | 10- 6.02 [1/32]  | 3281 | 10- 9.17 [11/64] |
| 2802 | 9- 2.31 [5/16]   | 2882 | 9- 5.46 [15/32]  | 2962 | 9- 8.61 [39/64]  | 3042 | 9-11.76 [49/64]  | 3122 | 10- 2.91 [29/32] | 3202 | 10- 6.06 [1/16]  | 3282 | 10- 9.21 [7/32]  |
| 2803 | 9- 2.35 [23/64]  | 2883 | 9- 5.50 [1/2]    | 2963 | 9- 8.65 [21/32]  | 3043 | 9-11.80 [51/64]  | 3123 | 10- 2.95 [61/64] | 3203 | 10- 6.10 [7/64]  | 3283 | 10- 9.25 [1/4]   |
| 2804 | 9- 2.39 [25/64]  | 2884 | 9- 5.54 [35/64]  | 2964 | 9- 8.69 [11/16]  | 3044 | 9-11.84 [27/32]  | 3124 | 10- 2.99 [63/64] | 3204 | 10- 6.14 [9/64]  | 3284 | 10- 9.29 [19/64] |
| 2805 | 9- 2.43 [7/16]   | 2885 | 9- 5.58 [37/64]  | 2965 | 9- 8.73 [47/64]  | 3045 | 9-11.88 [7/8]    | 3125 | 10- 3.03 [1/32]  | 3205 | 10- 6.18 [3/16]  | 3285 | 10- 9.33 [21/64] |
| 2806 | 9- 2.47 [15/32]  | 2886 | 9- 5.62 [5/8]    | 2966 | 9- 8.77 [49/64]  | 3046 | 9-11.92 [59/64]  | 3126 | 10- 3.07 [5/64]  | 3206 | 10- 6.22 [7/32]  | 3286 | 10- 9.37 [3/8]   |
| 2807 | 9- 2.51 [33/64]  | 2887 | 9- 5.66 [21/32]  | 2967 | 9- 8.81 [13/16]  | 3047 | 9-11.96 [61/64]  | 3127 | 10- 3.11 [7/64]  | 3207 | 10- 6.26 [17/64] | 3287 | 10- 9.41 [13/32] |
| 2808 | 9- 2.55 [35/64]  | 2888 | 9- 5.70 [45/64]  | 2968 | 9- 8.85 [27/32]  | 3048 | 10- 0.00         | 3128 | 10- 3.15 [5/32]  | 3208 | 10- 6.30 [19/64] | 3288 | 10- 9.45 [29/64] |
| 2809 | 9- 2.59 [19/32]  | 2889 | 9- 5.74 [47/64]  | 2969 | 9- 8.89 [57/64]  | 3049 | 10- 0.04 [3/64]  | 3129 | 10- 3.19 [3/16]  | 3209 | 10- 6.34 [11/32] | 3289 | 10- 9.49 [31/64] |
| 2810 | 9- 2.63 [5/8]    | 2890 | 9- 5.78 [25/32]  | 2970 | 9- 8.93 [59/64]  | 3050 | 10- 0.08 [5/64]  | 3130 | 10- 3.23 [15/64] | 3210 | 10- 6.38 [3/8]   | 3290 | 10- 9.53 [17/32] |
| 2811 | 9- 2.67 [43/64]  | 2891 | 9- 5.82 [13/16]  | 2971 | 9- 8.97 [31/32]  | 3051 | 10- 0.12 [1/8]   | 3131 | 10- 3.27 [17/64] | 3211 | 10- 6.42 [27/64] | 3291 | 10- 9.57 [9/16]  |
| 2812 | 9- 2.71 [45/64]  | 2892 | 9- 5.86 [55/64]  | 2972 | 9- 9.01 [1/64]   | 3052 | 10- 0.16 [5/32]  | 3132 | 10- 3.31 [5/16]  | 3212 | 10- 6.46 [29/64] | 3292 | 10- 9.61 [39/64] |
| 2813 | 9- 2.75 [3/4]    | 2893 | 9- 5.90 [57/64]  | 2973 | 9- 9.05 [3/64]   | 3053 | 10- 0.20 [13/64] | 3133 | 10- 3.35 [11/32] | 3213 | 10- 6.50 [1/2]   | 3293 | 10- 9.65 [41/64] |
| 2814 | 9- 2.79 [25/32]  | 2894 | 9- 5.94 [15/16]  | 2974 | 9- 9.09 [3/32]   | 3054 | 10- 0.24 [15/64] | 3134 | 10- 3.39 [25/64] | 3214 | 10- 6.54 [17/32] | 3294 | 10- 9.69 [11/16] |
| 2815 | 9- 2.83 [53/64]  | 2895 | 9- 5.98 [31/32]  | 2975 | 9- 9.13 [1/8]    | 3055 | 10- 0.28 [9/32]  | 3135 | 10- 3.43 [27/64] | 3215 | 10- 6.57 [37/64] | 3295 | 10- 9.72 [23/32] |
| 2816 | 9- 2.87 [55/64]  | 2896 | 9- 6.02 [1/64]   | 2976 | 9- 9.17 [11/64]  | 3056 | 10- 0.31 [5/16]  | 3136 | 10- 3.46 [15/32] | 3216 | 10- 6.61 [39/64] | 3296 | 10- 9.76 [49/64] |
| 2817 | 9- 2.91 [29/32]  | 2897 | 9- 6.06 [1/16]   | 2977 | 9- 9.20 [13/64]  | 3057 | 10- 0.35 [23/64] | 3137 | 10- 3.50 [1/2]   | 3217 | 10- 6.65 [21/32] | 3297 | 10- 9.80 [51/64] |
| 2818 | 9- 2.94 [15/16]  | 2898 | 9- 6.09 [3/32]   | 2978 | 9- 9.24 [1/4]    | 3058 | 10- 0.39 [25/64] | 3138 | 10- 3.54 [35/64] | 3218 | 10- 6.69 [11/16] | 3298 | 10- 9.84 [27/32] |
| 2819 | 9- 2.98 [63/64]  | 2899 | 9- 6.13 [9/64]   | 2979 | 9- 9.28 [9/32]   | 3059 | 10- 0.43 [7/16]  | 3139 | 10- 3.58 [37/64] | 3219 | 10- 6.73 [47/64] | 3299 | 10- 9.88 [7/8]   |
| 2820 | 9- 3.02 [1/32]   | 2900 | 9- 6.17 [11/64]  | 2980 | 9- 9.32 [21/64]  | 3060 | 10- 0.47 [15/32] | 3140 | 10- 3.62 [5/8]   | 3220 | 10- 6.77 [49/64] | 3300 | 10- 9.92 [59/64] |
| 2821 | 9- 3.06 [1/16]   | 2901 | 9- 6.21 [7/32]   | 2981 | 9- 9.36 [23/64]  | 3061 | 10- 0.51 [33/64] | 3141 | 10- 3.66 [21/32] | 3221 | 10- 6.81 [13/16] | 3301 | 10- 9.96 [61/64] |
| 2822 | 9- 3.10 [7/64]   | 2902 | 9- 6.25 [1/4]    | 2982 | 9- 9.40 [13/32]  | 3062 | 10- 0.55 [35/64] | 3142 | 10- 3.70 [45/64] | 3222 | 10- 6.85 [27/32] | 3302 | 10-10.00         |
| 2823 | 9- 3.14 [9/64]   | 2903 | 9- 6.29 [19/64]  | 2983 | 9- 9.44 [7/16]   | 3063 | 10- 0.59 [19/32] | 3143 | 10- 3.74 [47/64] | 3223 | 10- 6.89 [57/64] | 3303 | 10-10.04 [3/64]  |
| 2824 | 9- 3.18 [3/16]   | 2904 | 9- 6.33 [21/64]  | 2984 | 9- 9.48 [31/64]  | 3064 | 10- 0.63 [5/8]   | 3144 | 10- 3.78 [25/32] | 3224 | 10- 6.93 [59/64] | 3304 | 10-10.08 [5/64]  |
| 2825 | 9- 3.22 [7/32]   | 2905 | 9- 6.37 [3/8]    | 2985 | 9- 9.52 [33/64]  | 3065 | 10- 0.67 [43/64] | 3145 | 10- 3.82 [13/16] | 3225 | 10- 6.97 [31/32] | 3305 | 10-10.12 [1/8]   |
| 2826 | 9- 3.26 [17/64]  | 2906 | 9- 6.41 [13/32]  | 2986 | 9- 9.56 [9/16]   | 3066 | 10- 0.71 [45/64] | 3146 | 10- 3.86 [55/64] | 3226 | 10- 7.01 [1/64]  | 3306 | 10-10.16 [5/32]  |
| 2827 | 9- 3.30 [19/64]  | 2907 | 9- 6.45 [29/64]  | 2987 | 9- 9.60 [19/32]  | 3067 | 10- 0.75 [3/4]   | 3147 | 10- 3.90 [57/64] | 3227 | 10- 7.05 [3/64]  | 3307 | 10-10.20 [13/64] |
| 2828 | 9- 3.34 [11/32]  | 2908 | 9- 6.49 [31/64]  | 2988 | 9- 9.64 [41/64]  | 3068 | 10- 0.79 [25/32] | 3148 | 10- 3.94 [15/16] | 3228 | 10- 7.09 [3/32]  | 3308 | 10-10.24 [15/64] |
| 2829 | 9- 3.38 [3/8]    | 2909 | 9- 6.53 [17/32]  | 2989 | 9- 9.68 [43/64]  | 3069 | 10- 0.83 [53/64] | 3149 | 10- 3.98 [31/32] | 3229 | 10- 7.13 [1/8]   | 3309 | 10-10.28 [9/32]  |
| 2830 | 9- 3.42 [27/64]  | 2910 | 9- 6.57 [9/16]   | 2990 | 9- 9.72 [23/32]  | 3070 | 10- 0.87 [55/64] | 3150 | 10- 4.02 [1/64]  | 3230 | 10- 7.17 [11/64] | 3310 | 10-10.31 [5/16]  |
| 2831 | 9- 3.46 [29/64]  | 2911 | 9- 6.61 [39/64]  | 2991 | 9- 9.76 [3/4]    | 3071 | 10- 0.91 [29/32] | 3151 | 10- 4.06 [1/16]  | 3231 | 10- 7.20 [13/64] | 3311 | 10-10.35 [23/64] |
| 2832 | 9- 3.50 [1/2]    | 2912 | 9- 6.65 [41/64]  | 2992 | 9- 9.80 [51/64]  | 3072 | 10- 0.94 [15/16] | 3152 | 10- 4.09 [3/32]  | 3232 | 10- 7.24 [1/4]   | 3312 | 10-10.39 [25/64] |
| 2833 | 9- 3.54 [17/32]  | 2913 | 9- 6.69 [11/16]  | 2993 | 9- 9.83 [53/64]  | 3073 | 10- 0.98 [63/64] | 3153 | 10- 4.13 [9/64]  | 3233 | 10- 7.28 [9/32]  | 3313 | 10-10.43 [7/16]  |
| 2834 | 9- 3.57 [37/64]  | 2914 | 9- 6.72 [23/32]  | 2994 | 9- 9.87 [7/8]    | 3074 | 10- 1.02 [1/32]  | 3154 | 10- 4.17 [11/64] | 3234 | 10- 7.32 [21/64] | 3314 | 10-10.47 [15/32] |
| 2835 | 9- 3.61 [39/64]  | 2915 | 9- 6.76 [49/64]  | 2995 | 9- 9.91 [29/32]  | 3075 | 10- 1.06 [1/16]  | 3155 | 10- 4.21 [7/32]  | 3235 | 10- 7.36 [23/64] | 3315 | 10-10.51 [33/64] |
| 2836 | 9- 3.65 [21/32]  | 2916 | 9- 6.80 [51/64]  | 2996 | 9- 9.95 [61/64]  | 3076 | 10- 1.10 [7/64]  | 3156 | 10- 4.25 [1/4]   | 3236 | 10- 7.40 [13/32] | 3316 | 10-10.55 [35/64] |
| 2837 | 9- 3.69 [11/16]  | 2917 | 9- 6.84 [27/32]  | 2997 | 9- 9.99 [63/64]  | 3077 | 10- 1.14 [9/64]  | 3157 | 10- 4.29 [19/64] | 3237 | 10- 7.44 [7/16]  | 3317 | 10-10.59 [19/32] |
| 2838 | 9- 3.73 [47/64]  | 2918 | 9- 6.88 [7/8]    | 2998 | 9-10.03 [1/32]   | 3078 | 10- 1.18 [3/16]  | 3158 | 10- 4.33 [21/64] | 3238 | 10- 7.48 [31/64] | 3318 | 10-10.63 [5/8]   |
| 2839 | 9- 3.77 [49/64]  | 2919 | 9- 6.92 [59/64]  | 2999 | 9-10.07 [5/64]   | 3079 | 10- 1.22 [7/32]  | 3159 | 10- 4.37 [3/8]   | 3239 | 10- 7.52 [33/64] | 3319 | 10-10.67 [43/64] |
| 2840 | 9- 3.81 [13/16]  | 2920 | 9- 6.96 [61/64]  | 3000 | 9-10.11 [7/64]   | 3080 | 10- 1.26 [17/64] | 3160 | 10- 4.41 [13/32] | 3240 | 10- 7.56 [9/16]  | 3320 | 10-10.71 [45/64] |
| 2841 | 9- 3.85 [27/32]  | 2921 | 9- 7.00          | 3001 | 9-10.15 [5/32]   | 3081 | 10- 1.30 [19/64] | 3161 | 10- 4.45 [29/64] | 3241 | 10- 7.60 [19/32] | 3321 | 10-10.75 [3/4]   |
| 2842 | 9- 3.89 [57/64]  | 2922 | 9- 7.04 [3/64]   | 3002 | 9-10.19 [3/16]   | 3082 | 10- 1.34 [11/32] | 3162 | 10- 4.49 [31/64] | 3242 | 10- 7.64 [41/64] | 3322 | 10-10.79 [25/32] |
| 2843 | 9- 3.93 [59/64]  | 2923 | 9- 7.08 [5/64]   | 3003 | 9-10.23 [15/64]  | 3083 | 10- 1.38 [3/8]   | 3163 | 10- 4.53 [17/32] | 3243 | 10- 7.68 [43/64] | 3323 | 10-10.83 [53/64] |
| 2844 | 9- 3.97 [31/32]  | 2924 | 9- 7.12 [1/8]    | 3004 | 9-10.27 [17/64]  | 3084 | 10- 1.42 [27/64] | 3164 | 10- 4.57 [9/16]  | 3244 | 10- 7.72 [23/32] | 3324 | 10-10.87 [55/64] |
| 2845 | 9- 4.01 [1/64]   | 2925 | 9- 7.16 [5/32]   | 3005 | 9-10.31 [5/16]   | 3085 | 10- 1.46 [29/64] | 3165 | 10- 4.61 [39/64] | 3245 | 10- 7.76 [3/4]   | 3325 | 10-10.91 [29/32] |
| 2846 | 9- 4.05 [3/64]   | 2926 | 9- 7.20 [13/64]  | 3006 | 9-10.35 [11/32]  | 3086 | 10- 1.50 [1/2]   | 3166 | 10- 4.65 [41/64] | 3246 | 10- 7.80 [51/64] | 3326 | 10-10.94 [15/16] |
| 2847 | 9- 4.09 [3/32]   | 2927 | 9- 7.24 [15/64]  | 3007 | 9-10.39 [25/64]  | 3087 | 10- 1.54 [17/32] | 3167 | 10- 4.69 [11/16] | 3247 | 10- 7.84 [53/64] | 3327 | 10-10.98 [63/64] |
| 2848 | 9- 4.13 [1/8]    | 2928 | 9- 7.28 [9/32]   | 3008 | 9-10.43 [27/64]  | 3088 | 10- 1.57 [37/64] | 3168 | 10- 4.72 [23/32] | 3248 | 10- 7.87 [7/8]   | 3328 | 10-11.02 [1/32]  |
| 2849 | 9- 4.17 [11/64]  | 2929 | 9- 7.31 [5/16]   | 3009 | 9-10.46 [15/32]  | 3089 | 10- 1.61 [39/64] | 3169 | 10- 4.76 [49/64] | 3249 | 10- 7.91 [29/32] | 3329 | 10-11.06 [1/16]  |
| 2850 | 9- 4.20 [13/64]  | 2930 | 9- 7.35 [23/64]  | 3010 | 9-10.50 [1/2]    | 3090 | 10- 1.65 [21/32] | 3170 | 10- 4.80 [51/64] | 3250 | 10- 7.95 [61/64] | 3330 | 10-11.10 [7/64]  |
| 2851 | 9- 4.24 [1/4]    | 2931 | 9- 7.39 [25/64]  | 3011 | 9-10.54 [35/64]  | 3091 | 10- 1.69 [11/16] | 3171 | 10- 4.84 [27/32] | 3251 | 10- 7.99 [63/64] | 3331 | 10-11.14 [9/64]  |
| 2852 | 9- 4.28 [9/32]   | 2932 | 9- 7.43 [7/16]   | 3012 | 9-10.58 [37/64]  | 3092 | 10- 1.73 [47/64] | 3172 | 10- 4.88 [7/8]   | 3252 | 10- 8.03 [1/32]  | 3332 | 10-11.18 [3/16]  |
| 2853 | 9- 4.32 [21/64]  | 2933 | 9- 7.47 [15/32]  | 3013 | 9-10.62 [5/8]    | 3093 | 10- 1.77 [49/64] | 3173 | 10- 4.92 [59/64] | 3253 | 10- 8.07 [5/64]  | 3333 | 10-11.22 [7/32]  |
| 2854 | 9- 4.36 [23/64]  | 2934 | 9- 7.51 [33/64]  | 3014 | 9-10.66 [21/32]  | 3094 | 10- 1.81 [13/16] | 3174 | 10- 4.96 [61/64] | 3254 | 10- 8.11 [7/64]  | 3334 | 10-11.26 [17/64] |
| 2855 | 9- 4.40 [13/32]  | 2935 | 9- 7.55 [35/64]  | 3015 | 9-10.70 [45/64]  | 3095 | 10- 1.85 [27/32] | 3175 | 10- 5.00         | 3255 | 10- 8.15 [5/32]  | 3335 | 10-11.30 [19/64] |
| 2856 | 9- 4.44 [7/16]   | 2936 | 9- 7.59 [19/32]  | 3016 | 9-10.74 [47/64]  | 3096 | 10- 1.89 [57/64] | 3176 | 10- 5.04 [3/64]  | 3256 | 10- 8.19 [3/16]  | 3336 | 10-11.34 [11/32] |
| 2857 | 9- 4.48 [31/64]  | 2937 | 9- 7.63 [5/8]    | 3017 | 9-10.78 [25/32]  | 3097 | 10- 1.93 [59/64] | 3177 | 10- 5.08 [5/64]  | 3257 | 10- 8.23 [15/64] | 3337 | 10-11.38 [3/8]   |
| 2858 | 9- 4.52 [33/64]  | 2938 | 9- 7.67 [43/64]  | 3018 | 9-10.82 [13/16]  | 3098 | 10- 1.97 [31/32] | 3178 | 10- 5.12 [1/8]   | 3258 | 10- 8.27 [17/64] | 3338 | 10-11.42 [27/64] |
| 2859 | 9- 4.56 [9/16]   | 2939 | 9- 7.71 [45/64]  | 3019 | 9-10.86 [55/64]  | 3099 | 10- 2.01 [1/64]  | 3179 | 10- 5.16 [5/32]  | 3259 | 10- 8.31 [5/16]  | 3339 | 10-11.46 [29/64] |
| 2860 | 9- 4.60 [19/32]  | 2940 | 9- 7.75 [3/4]    | 3020 | 9-10.90 [57/64]  | 3100 | 10- 2.05 [3/64]  | 3180 | 10- 5.20 [13/64] | 3260 | 10- 8.35 [11/32] | 3340 | 10-11.50 [1/2]   |
| 2861 | 9- 4.64 [41/64]  | 2941 | 9- 7.79 [25/32]  | 3021 | 9-10.94 [15/16]  | 3101 | 10- 2.09 [3/32]  | 3181 | 10- 5.24 [15/64] | 3261 | 10- 8.39 [25/64] | 3341 | 10-11.54 [17/32] |
| 2862 | 9- 4.68 [43/64]  | 2942 | 9- 7.83 [53/64]  | 3022 | 9-10.98 [31/32]  | 3102 | 10- 2.13 [1/8]   | 3182 | 10- 5.28 [9/32]  | 3262 | 10- 8.43 [27/64] | 3342 | 10-11.57 [37/64] |
| 2863 | 9- 4.72 [23/32]  | 2943 | 9- 7.87 [55/64]  | 3023 | 9-11.02 [1/64]   | 3103 | 10- 2.17 [11     |      |                  |      |                  |      |                  |

# MILLIMETERS CONVERTED TO FEET AND INCHES

# TABLES M-3

| mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) |
|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|
| 3361 | 11- 0.32 [21/64] | 3441 | 11- 3.47 [15/32] | 3521 | 11- 6.62 [5/8]   | 3601 | 11- 9.77 [49/64] | 3681 | 12- 0.92 [59/64] | 3761 | 12- 4.07 [5/64]  | 3841 | 12- 7.22 [7/32]  |
| 3362 | 11- 0.36 [23/64] | 3442 | 11- 3.51 [33/64] | 3522 | 11- 6.66 [21/32] | 3602 | 11- 9.81 [13/16] | 3682 | 12- 0.96 [61/64] | 3762 | 12- 4.11 [7/64]  | 3842 | 12- 7.26 [17/64] |
| 3363 | 11- 0.40 [13/32] | 3443 | 11- 3.55 [35/64] | 3523 | 11- 6.70 [45/64] | 3603 | 11- 9.85 [27/32] | 3683 | 12- 1.00 [3/64]  | 3763 | 12- 4.15 [5/32]  | 3843 | 12- 7.30 [19/64] |
| 3364 | 11- 0.44 [7/16]  | 3444 | 11- 3.59 [19/32] | 3524 | 11- 6.74 [47/64] | 3604 | 11- 9.89 [57/64] | 3684 | 12- 1.04 [3/64]  | 3764 | 12- 4.19 [3/16]  | 3844 | 12- 7.34 [11/32] |
| 3365 | 11- 0.48 [31/64] | 3445 | 11- 3.63 [5/8]   | 3525 | 11- 6.78 [25/32] | 3605 | 11- 9.93 [59/64] | 3685 | 12- 1.08 [5/64]  | 3765 | 12- 4.23 [15/64] | 3845 | 12- 7.38 [3/8]   |
| 3366 | 11- 0.52 [33/64] | 3446 | 11- 3.67 [43/64] | 3526 | 11- 6.82 [13/16] | 3606 | 11- 9.97 [31/32] | 3686 | 12- 1.12 [1/8]   | 3766 | 12- 4.27 [17/64] | 3846 | 12- 7.42 [27/64] |
| 3367 | 11- 0.56 [9/16]  | 3447 | 11- 3.71 [45/64] | 3527 | 11- 6.86 [55/64] | 3607 | 11-10.01 [1/64]  | 3687 | 12- 1.16 [5/32]  | 3767 | 12- 4.31 [5/16]  | 3847 | 12- 7.46 [29/64] |
| 3368 | 11- 0.60 [19/32] | 3448 | 11- 3.75 [3/4]   | 3528 | 11- 6.90 [57/64] | 3608 | 11-10.05 [3/64]  | 3688 | 12- 1.20 [13/64] | 3768 | 12- 4.35 [11/32] | 3848 | 12- 7.50 [1/2]   |
| 3369 | 11- 0.64 [41/64] | 3449 | 11- 3.79 [25/32] | 3529 | 11- 6.94 [15/16] | 3609 | 11-10.09 [3/32]  | 3689 | 12- 1.24 [15/64] | 3769 | 12- 4.39 [25/64] | 3849 | 12- 7.54 [17/32] |
| 3370 | 11- 0.68 [43/64] | 3450 | 11- 3.83 [53/64] | 3530 | 11- 6.98 [31/32] | 3610 | 11-10.13 [1/8]   | 3690 | 12- 1.28 [9/32]  | 3770 | 12- 4.43 [27/64] | 3850 | 12- 7.57 [37/64] |
| 3371 | 11- 0.72 [23/32] | 3451 | 11- 3.87 [55/64] | 3531 | 11- 7.02 [1/64]  | 3611 | 11-10.17 [11/64] | 3691 | 12- 1.31 [5/16]  | 3771 | 12- 4.46 [15/32] | 3851 | 12- 7.61 [39/64] |
| 3372 | 11- 0.76 [3/4]   | 3452 | 11- 3.91 [29/32] | 3532 | 11- 7.06 [1/16]  | 3612 | 11-10.20 [13/64] | 3692 | 12- 1.35 [23/64] | 3772 | 12- 4.50 [1/2]   | 3852 | 12- 7.65 [21/32] |
| 3373 | 11- 0.80 [51/64] | 3453 | 11- 3.94 [15/16] | 3533 | 11- 7.09 [3/32]  | 3613 | 11-10.24 [1/4]   | 3693 | 12- 1.39 [25/64] | 3773 | 12- 4.54 [35/64] | 3853 | 12- 7.69 [11/16] |
| 3374 | 11- 0.83 [53/64] | 3454 | 11- 3.98 [63/64] | 3534 | 11- 7.13 [9/64]  | 3614 | 11-10.28 [9/32]  | 3694 | 12- 1.43 [7/16]  | 3774 | 12- 4.58 [37/64] | 3854 | 12- 7.73 [47/64] |
| 3375 | 11- 0.87 [7/8]   | 3455 | 11- 4.02 [1/32]  | 3535 | 11- 7.17 [11/64] | 3615 | 11-10.32 [21/64] | 3695 | 12- 1.47 [15/32] | 3775 | 12- 4.62 [5/8]   | 3855 | 12- 7.77 [49/64] |
| 3376 | 11- 0.91 [29/32] | 3456 | 11- 4.06 [1/16]  | 3536 | 11- 7.21 [7/32]  | 3616 | 11-10.36 [23/64] | 3696 | 12- 1.51 [33/64] | 3776 | 12- 4.66 [21/32] | 3856 | 12- 7.81 [13/16] |
| 3377 | 11- 0.95 [61/64] | 3457 | 11- 4.10 [7/64]  | 3537 | 11- 7.25 [1/4]   | 3617 | 11-10.40 [13/32] | 3697 | 12- 1.55 [35/64] | 3777 | 12- 4.70 [45/64] | 3857 | 12- 7.85 [27/32] |
| 3378 | 11- 0.99 [63/64] | 3458 | 11- 4.14 [9/64]  | 3538 | 11- 7.29 [19/64] | 3618 | 11-10.44 [7/16]  | 3698 | 12- 1.59 [19/32] | 3778 | 12- 4.74 [47/64] | 3858 | 12- 7.89 [57/64] |
| 3379 | 11- 1.03 [1/32]  | 3459 | 11- 4.18 [3/16]  | 3539 | 11- 7.33 [21/64] | 3619 | 11-10.48 [31/64] | 3699 | 12- 1.63 [5/8]   | 3779 | 12- 4.78 [25/32] | 3859 | 12- 7.93 [59/64] |
| 3380 | 11- 1.07 [5/64]  | 3460 | 11- 4.22 [7/32]  | 3540 | 11- 7.37 [3/8]   | 3620 | 11-10.52 [33/64] | 3700 | 12- 1.67 [43/64] | 3780 | 12- 4.82 [13/16] | 3860 | 12- 7.97 [31/32] |
| 3381 | 11- 1.11 [7/64]  | 3461 | 11- 4.26 [17/64] | 3541 | 11- 7.41 [13/32] | 3621 | 11-10.56 [9/16]  | 3701 | 12- 1.71 [45/64] | 3781 | 12- 4.86 [55/64] | 3861 | 12- 8.01 [1/64]  |
| 3382 | 11- 1.15 [5/32]  | 3462 | 11- 4.30 [19/64] | 3542 | 11- 7.45 [29/64] | 3622 | 11-10.60 [19/32] | 3702 | 12- 1.75 [3/4]   | 3782 | 12- 4.90 [57/64] | 3862 | 12- 8.05 [3/64]  |
| 3383 | 11- 1.19 [3/16]  | 3463 | 11- 4.34 [31/64] | 3543 | 11- 7.49 [31/64] | 3623 | 11-10.64 [41/64] | 3703 | 12- 1.79 [25/32] | 3783 | 12- 4.94 [15/16] | 3863 | 12- 8.09 [3/32]  |
| 3384 | 11- 1.23 [15/64] | 3464 | 11- 4.38 [3/8]   | 3544 | 11- 7.53 [17/32] | 3624 | 11-10.68 [43/64] | 3704 | 12- 1.83 [53/64] | 3784 | 12- 4.98 [31/32] | 3864 | 12- 8.13 [1/8]   |
| 3385 | 11- 1.27 [17/64] | 3465 | 11- 4.42 [27/64] | 3545 | 11- 7.57 [9/16]  | 3625 | 11-10.72 [23/32] | 3705 | 12- 1.87 [55/64] | 3785 | 12- 5.02 [1/64]  | 3865 | 12- 8.17 [11/64] |
| 3386 | 11- 1.31 [5/16]  | 3466 | 11- 4.46 [29/64] | 3546 | 11- 7.61 [39/64] | 3626 | 11-10.76 [3/4]   | 3706 | 12- 1.91 [29/32] | 3786 | 12- 5.06 [1/16]  | 3866 | 12- 8.20 [13/64] |
| 3387 | 11- 1.35 [11/32] | 3467 | 11- 4.50 [1/2]   | 3547 | 11- 7.65 [41/64] | 3627 | 11-10.80 [51/64] | 3707 | 12- 1.94 [15/16] | 3787 | 12- 5.09 [3/32]  | 3867 | 12- 8.24 [1/4]   |
| 3388 | 11- 1.39 [25/64] | 3468 | 11- 4.54 [17/32] | 3548 | 11- 7.69 [11/16] | 3628 | 11-10.83 [53/64] | 3708 | 12- 1.98 [63/64] | 3788 | 12- 5.13 [9/64]  | 3868 | 12- 8.28 [9/32]  |
| 3389 | 11- 1.43 [27/64] | 3469 | 11- 4.57 [37/64] | 3549 | 11- 7.72 [23/32] | 3629 | 11-10.87 [7/8]   | 3709 | 12- 2.02 [1/32]  | 3789 | 12- 5.17 [11/64] | 3869 | 12- 8.32 [21/64] |
| 3390 | 11- 1.46 [15/32] | 3470 | 11- 4.61 [39/64] | 3550 | 11- 7.76 [49/64] | 3630 | 11-10.91 [29/32] | 3710 | 12- 2.06 [1/16]  | 3790 | 12- 5.21 [7/32]  | 3870 | 12- 8.36 [23/64] |
| 3391 | 11- 1.50 [1/2]   | 3471 | 11- 4.65 [21/32] | 3551 | 11- 7.80 [51/64] | 3631 | 11-10.95 [61/64] | 3711 | 12- 2.10 [7/64]  | 3791 | 12- 5.25 [1/4]   | 3871 | 12- 8.40 [13/32] |
| 3392 | 11- 1.54 [35/64] | 3472 | 11- 4.69 [11/16] | 3552 | 11- 7.84 [27/32] | 3632 | 11-10.99 [63/64] | 3712 | 12- 2.14 [9/64]  | 3792 | 12- 5.29 [19/64] | 3872 | 12- 8.44 [7/16]  |
| 3393 | 11- 1.58 [37/64] | 3473 | 11- 4.73 [47/64] | 3553 | 11- 7.88 [7/8]   | 3633 | 11-11.03 [1/32]  | 3713 | 12- 2.18 [3/16]  | 3793 | 12- 5.33 [21/64] | 3873 | 12- 8.48 [31/64] |
| 3394 | 11- 1.62 [5/8]   | 3474 | 11- 4.77 [49/64] | 3554 | 11- 7.92 [59/64] | 3634 | 11-11.07 [5/64]  | 3714 | 12- 2.22 [7/32]  | 3794 | 12- 5.37 [3/8]   | 3874 | 12- 8.52 [33/64] |
| 3395 | 11- 1.66 [21/32] | 3475 | 11- 4.81 [13/16] | 3555 | 11- 7.96 [61/64] | 3635 | 11-11.11 [7/64]  | 3715 | 12- 2.26 [17/64] | 3795 | 12- 5.41 [13/32] | 3875 | 12- 8.56 [9/16]  |
| 3396 | 11- 1.70 [45/64] | 3476 | 11- 4.85 [27/32] | 3556 | 11- 8.00 [3/4]   | 3636 | 11-11.15 [5/32]  | 3716 | 12- 2.30 [19/64] | 3796 | 12- 5.45 [29/64] | 3876 | 12- 8.60 [19/32] |
| 3397 | 11- 1.74 [47/64] | 3477 | 11- 4.89 [57/64] | 3557 | 11- 8.04 [3/64]  | 3637 | 11-11.19 [3/16]  | 3717 | 12- 2.34 [11/32] | 3797 | 12- 5.49 [31/64] | 3877 | 12- 8.64 [41/64] |
| 3398 | 11- 1.78 [25/32] | 3478 | 11- 4.93 [59/64] | 3558 | 11- 8.08 [5/64]  | 3638 | 11-11.23 [15/64] | 3718 | 12- 2.38 [3/8]   | 3798 | 12- 5.53 [17/32] | 3878 | 12- 8.68 [43/64] |
| 3399 | 11- 1.82 [13/16] | 3479 | 11- 4.97 [31/32] | 3559 | 11- 8.12 [1/8]   | 3639 | 11-11.27 [17/64] | 3719 | 12- 2.42 [27/64] | 3799 | 12- 5.57 [9/16]  | 3879 | 12- 8.72 [23/32] |
| 3400 | 11- 1.86 [55/64] | 3480 | 11- 5.01 [1/64]  | 3560 | 11- 8.16 [5/32]  | 3640 | 11-11.31 [5/16]  | 3720 | 12- 2.46 [29/64] | 3800 | 12- 5.61 [39/64] | 3880 | 12- 8.76 [3/4]   |
| 3401 | 11- 1.90 [57/64] | 3481 | 11- 5.05 [3/64]  | 3561 | 11- 8.20 [13/64] | 3641 | 11-11.35 [11/32] | 3721 | 12- 2.50 [1/2]   | 3801 | 12- 5.65 [41/64] | 3881 | 12- 8.80 [51/64] |
| 3402 | 11- 1.94 [15/16] | 3482 | 11- 5.09 [3/32]  | 3562 | 11- 8.24 [15/64] | 3642 | 11-11.39 [25/64] | 3722 | 12- 2.54 [17/32] | 3802 | 12- 5.69 [11/16] | 3882 | 12- 8.83 [53/64] |
| 3403 | 11- 1.98 [31/32] | 3483 | 11- 5.13 [1/8]   | 3563 | 11- 8.28 [9/32]  | 3643 | 11-11.43 [27/64] | 3723 | 12- 2.57 [37/64] | 3803 | 12- 5.72 [23/32] | 3883 | 12- 8.87 [7/8]   |
| 3404 | 11- 2.02 [1/64]  | 3484 | 11- 5.17 [11/64] | 3564 | 11- 8.31 [5/16]  | 3644 | 11-11.46 [15/32] | 3724 | 12- 2.61 [39/64] | 3804 | 12- 5.76 [49/64] | 3884 | 12- 8.91 [29/32] |
| 3405 | 11- 2.06 [1/16]  | 3485 | 11- 5.20 [13/64] | 3565 | 11- 8.35 [23/64] | 3645 | 11-11.50 [1/2]   | 3725 | 12- 2.65 [21/32] | 3805 | 12- 5.80 [51/64] | 3885 | 12- 8.95 [61/64] |
| 3406 | 11- 2.09 [3/32]  | 3486 | 11- 5.24 [1/4]   | 3566 | 11- 8.39 [25/64] | 3646 | 11-11.54 [35/64] | 3726 | 12- 2.69 [11/16] | 3806 | 12- 5.84 [27/32] | 3886 | 12- 8.99 [63/64] |
| 3407 | 11- 2.13 [9/64]  | 3487 | 11- 5.28 [9/32]  | 3567 | 11- 8.43 [7/16]  | 3647 | 11-11.58 [37/64] | 3727 | 12- 2.73 [47/64] | 3807 | 12- 5.88 [7/8]   | 3887 | 12- 9.03 [1/32]  |
| 3408 | 11- 2.17 [11/64] | 3488 | 11- 5.32 [21/64] | 3568 | 11- 8.47 [15/32] | 3648 | 11-11.62 [5/8]   | 3728 | 12- 2.77 [49/64] | 3808 | 12- 5.92 [59/64] | 3888 | 12- 9.07 [5/64]  |
| 3409 | 11- 2.21 [7/32]  | 3489 | 11- 5.36 [23/64] | 3569 | 11- 8.51 [33/64] | 3649 | 11-11.66 [21/32] | 3729 | 12- 2.81 [13/16] | 3809 | 12- 5.96 [61/64] | 3889 | 12- 9.11 [7/64]  |
| 3410 | 11- 2.25 [1/4]   | 3490 | 11- 5.40 [13/32] | 3570 | 11- 8.55 [35/64] | 3650 | 11-11.70 [45/64] | 3730 | 12- 2.85 [27/32] | 3810 | 12- 6.00 [3/4]   | 3890 | 12- 9.15 [5/32]  |
| 3411 | 11- 2.29 [19/64] | 3491 | 11- 5.44 [7/16]  | 3571 | 11- 8.59 [19/32] | 3651 | 11-11.74 [47/64] | 3731 | 12- 2.89 [57/64] | 3811 | 12- 6.04 [3/64]  | 3891 | 12- 9.19 [3/16]  |
| 3412 | 11- 2.33 [21/64] | 3492 | 11- 5.48 [31/64] | 3572 | 11- 8.63 [5/8]   | 3652 | 11-11.78 [25/32] | 3732 | 12- 2.93 [59/64] | 3812 | 12- 6.08 [5/64]  | 3892 | 12- 9.23 [15/64] |
| 3413 | 11- 2.37 [3/8]   | 3493 | 11- 5.52 [33/64] | 3573 | 11- 8.67 [43/64] | 3653 | 11-11.82 [13/16] | 3733 | 12- 2.97 [31/32] | 3813 | 12- 6.12 [1/8]   | 3893 | 12- 9.27 [17/64] |
| 3414 | 11- 2.41 [13/32] | 3494 | 11- 5.56 [9/16]  | 3574 | 11- 8.71 [45/64] | 3654 | 11-11.86 [55/64] | 3734 | 12- 3.01 [1/64]  | 3814 | 12- 6.16 [5/32]  | 3894 | 12- 9.31 [5/16]  |
| 3415 | 11- 2.45 [29/64] | 3495 | 11- 5.60 [19/32] | 3575 | 11- 8.75 [3/4]   | 3655 | 11-11.90 [57/64] | 3735 | 12- 3.05 [3/64]  | 3815 | 12- 6.20 [13/64] | 3895 | 12- 9.35 [11/32] |
| 3416 | 11- 2.49 [31/64] | 3496 | 11- 5.64 [41/64] | 3576 | 11- 8.79 [25/32] | 3656 | 11-11.94 [15/16] | 3736 | 12- 3.09 [3/32]  | 3816 | 12- 6.24 [15/64] | 3896 | 12- 9.39 [25/64] |
| 3417 | 11- 2.53 [17/32] | 3497 | 11- 5.68 [43/64] | 3577 | 11- 8.83 [53/64] | 3657 | 11-11.98 [31/32] | 3737 | 12- 3.13 [1/8]   | 3817 | 12- 6.28 [9/32]  | 3897 | 12- 9.43 [27/64] |
| 3418 | 11- 2.57 [9/16]  | 3498 | 11- 5.72 [23/32] | 3578 | 11- 8.87 [55/64] | 3658 | 12- 0.02 [1/64]  | 3738 | 12- 3.17 [11/64] | 3818 | 12- 6.31 [5/16]  | 3898 | 12- 9.46 [15/32] |
| 3419 | 11- 2.61 [39/64] | 3499 | 11- 5.76 [3/4]   | 3579 | 11- 8.91 [29/32] | 3659 | 12- 0.06 [1/16]  | 3739 | 12- 3.20 [13/64] | 3819 | 12- 6.35 [23/64] | 3899 | 12- 9.50 [1/2]   |
| 3420 | 11- 2.65 [41/64] | 3500 | 11- 5.80 [51/64] | 3580 | 11- 8.94 [15/16] | 3660 | 12- 0.09 [3/32]  | 3740 | 12- 3.24 [1/4]   | 3820 | 12- 6.39 [25/64] | 3900 | 12- 9.54 [35/64] |
| 3421 | 11- 2.69 [11/16] | 3501 | 11- 5.83 [53/64] | 3581 | 11- 8.98 [63/64] | 3661 | 12- 0.13 [9/64]  | 3741 | 12- 3.28 [9/32]  | 3821 | 12- 6.43 [7/16]  | 3901 | 12- 9.58 [37/64] |
| 3422 | 11- 2.72 [23/32] | 3502 | 11- 5.87 [7/8]   | 3582 | 11- 9.02 [1/32]  | 36   |                  |      |                  |      |                  |      |                  |

# MILLIMETERS CONVERTED TO FEET AND INCHES

# TABLES M-3

| mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) |
|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|
| 3921 | 12-10.37 [3/8]   | 4001 | 13- 1.52 [33/64] | 4081 | 13- 4.67 [43/64] | 4161 | 13- 7.82 [13/16] | 4241 | 13-10.97 [31/32] | 4321 | 14- 2.12 [1/8]   | 4401 | 14- 5.27 [17/64] |
| 3922 | 12-10.41 [13/32] | 4002 | 13- 1.56 [9/16]  | 4082 | 13- 4.71 [45/64] | 4162 | 13- 7.86 [55/64] | 4242 | 13-11.01 [1/64]  | 4322 | 14- 2.16 [5/32]  | 4402 | 14- 5.31 [5/16]  |
| 3923 | 12-10.45 [29/64] | 4003 | 13- 1.60 [19/32] | 4083 | 13- 4.75 [3/4]   | 4163 | 13- 7.90 [57/64] | 4243 | 13-11.05 [3/64]  | 4323 | 14- 2.20 [13/64] | 4403 | 14- 5.35 [11/32] |
| 3924 | 12-10.49 [31/64] | 4004 | 13- 1.64 [41/64] | 4084 | 13- 4.79 [25/32] | 4164 | 13- 7.94 [15/16] | 4244 | 13-11.09 [3/32]  | 4324 | 14- 2.24 [15/64] | 4404 | 14- 5.39 [25/64] |
| 3925 | 12-10.53 [17/32] | 4005 | 13- 1.68 [43/64] | 4085 | 13- 4.83 [53/64] | 4165 | 13- 7.98 [31/32] | 4245 | 13-11.13 [1/8]   | 4325 | 14- 2.28 [9/32]  | 4405 | 14- 5.43 [27/64] |
| 3926 | 12-10.57 [9/16]  | 4006 | 13- 1.72 [23/32] | 4086 | 13- 4.87 [55/64] | 4166 | 13- 8.02 [1/64]  | 4246 | 13-11.17 [11/64] | 4326 | 14- 2.31 [5/16]  | 4406 | 14- 5.46 [15/32] |
| 3927 | 12-10.61 [39/64] | 4007 | 13- 1.76 [3/4]   | 4087 | 13- 4.91 [29/32] | 4167 | 13- 8.06 [1/16]  | 4247 | 13-11.20 [13/64] | 4327 | 14- 2.35 [23/64] | 4407 | 14- 5.50 [1/2]   |
| 3928 | 12-10.65 [41/64] | 4008 | 13- 1.80 [51/64] | 4088 | 13- 4.94 [15/16] | 4168 | 13- 8.09 [3/32]  | 4248 | 13-11.24 [1/4]   | 4328 | 14- 2.39 [25/64] | 4408 | 14- 5.54 [35/64] |
| 3929 | 12-10.69 [11/16] | 4009 | 13- 1.83 [53/64] | 4089 | 13- 4.98 [63/64] | 4169 | 13- 8.13 [9/64]  | 4249 | 13-11.28 [9/32]  | 4329 | 14- 2.43 [7/16]  | 4409 | 14- 5.58 [37/64] |
| 3930 | 12-10.72 [23/32] | 4010 | 13- 1.87 [7/8]   | 4090 | 13- 5.02 [1/32]  | 4170 | 13- 8.17 [11/64] | 4250 | 13-11.32 [21/64] | 4330 | 14- 2.47 [15/32] | 4410 | 14- 5.62 [5/8]   |
| 3931 | 12-10.76 [49/64] | 4011 | 13- 1.91 [29/32] | 4091 | 13- 5.06 [1/16]  | 4171 | 13- 8.21 [7/32]  | 4251 | 13-11.36 [23/64] | 4331 | 14- 2.51 [33/64] | 4411 | 14- 5.66 [21/32] |
| 3932 | 12-10.80 [51/64] | 4012 | 13- 1.95 [61/64] | 4092 | 13- 5.10 [7/64]  | 4172 | 13- 8.25 [1/4]   | 4252 | 13-11.40 [13/32] | 4332 | 14- 2.55 [35/64] | 4412 | 14- 5.70 [45/64] |
| 3933 | 12-10.84 [27/32] | 4013 | 13- 1.99 [63/64] | 4093 | 13- 5.14 [9/64]  | 4173 | 13- 8.29 [19/64] | 4253 | 13-11.44 [7/16]  | 4333 | 14- 2.59 [19/32] | 4413 | 14- 5.74 [47/64] |
| 3934 | 12-10.88 [7/8]   | 4014 | 13- 2.03 [1/32]  | 4094 | 13- 5.18 [3/16]  | 4174 | 13- 8.33 [21/64] | 4254 | 13-11.48 [31/64] | 4334 | 14- 2.63 [5/8]   | 4414 | 14- 5.78 [25/32] |
| 3935 | 12-10.92 [59/64] | 4015 | 13- 2.07 [5/64]  | 4095 | 13- 5.22 [7/32]  | 4175 | 13- 8.37 [3/8]   | 4255 | 13-11.52 [33/64] | 4335 | 14- 2.67 [43/64] | 4415 | 14- 5.82 [13/16] |
| 3936 | 12-10.96 [61/64] | 4016 | 13- 2.11 [7/64]  | 4096 | 13- 5.26 [17/64] | 4176 | 13- 8.41 [13/32] | 4256 | 13-11.56 [9/16]  | 4336 | 14- 2.71 [45/64] | 4416 | 14- 5.86 [55/64] |
| 3937 | 12-11.00         | 4017 | 13- 2.15 [5/32]  | 4097 | 13- 5.30 [19/64] | 4177 | 13- 8.45 [29/64] | 4257 | 13-11.60 [19/32] | 4337 | 14- 2.75 [3/4]   | 4417 | 14- 5.90 [57/64] |
| 3938 | 12-11.04 [3/64]  | 4018 | 13- 2.19 [3/16]  | 4098 | 13- 5.34 [11/32] | 4178 | 13- 8.49 [31/64] | 4258 | 13-11.64 [41/64] | 4338 | 14- 2.79 [25/32] | 4418 | 14- 5.94 [15/16] |
| 3939 | 12-11.08 [5/64]  | 4019 | 13- 2.23 [15/64] | 4099 | 13- 5.38 [3/8]   | 4179 | 13- 8.53 [17/32] | 4259 | 13-11.68 [43/64] | 4339 | 14- 2.83 [53/64] | 4419 | 14- 5.98 [31/32] |
| 3940 | 12-11.12 [1/8]   | 4020 | 13- 2.27 [17/64] | 4100 | 13- 5.42 [27/64] | 4180 | 13- 8.57 [9/16]  | 4260 | 13-11.72 [23/32] | 4340 | 14- 2.87 [55/64] | 4420 | 14- 6.02 [1/64]  |
| 3941 | 12-11.16 [5/32]  | 4021 | 13- 2.31 [5/16]  | 4101 | 13- 5.46 [29/64] | 4181 | 13- 8.61 [39/64] | 4261 | 13-11.76 [3/4]   | 4341 | 14- 2.91 [29/32] | 4421 | 14- 6.06 [1/16]  |
| 3942 | 12-11.20 [13/64] | 4022 | 13- 2.35 [11/32] | 4102 | 13- 5.50 [1/2]   | 4182 | 13- 8.65 [41/64] | 4262 | 13-11.80 [51/64] | 4342 | 14- 2.94 [15/16] | 4422 | 14- 6.09 [3/32]  |
| 3943 | 12-11.24 [15/64] | 4023 | 13- 2.39 [25/64] | 4103 | 13- 5.54 [17/32] | 4183 | 13- 8.69 [11/16] | 4263 | 13-11.83 [53/64] | 4343 | 14- 2.98 [63/64] | 4423 | 14- 6.13 [9/64]  |
| 3944 | 12-11.28 [9/32]  | 4024 | 13- 2.43 [27/64] | 4104 | 13- 5.57 [37/64] | 4184 | 13- 8.72 [23/32] | 4264 | 13-11.87 [7/8]   | 4344 | 14- 3.02 [1/32]  | 4424 | 14- 6.17 [11/64] |
| 3945 | 12-11.31 [5/16]  | 4025 | 13- 2.46 [15/32] | 4105 | 13- 5.61 [39/64] | 4185 | 13- 8.76 [49/64] | 4265 | 13-11.91 [29/32] | 4345 | 14- 3.06 [1/16]  | 4425 | 14- 6.21 [7/32]  |
| 3946 | 12-11.35 [23/64] | 4026 | 13- 2.50 [1/2]   | 4106 | 13- 5.65 [21/32] | 4186 | 13- 8.80 [51/64] | 4266 | 13-11.95 [61/64] | 4346 | 14- 3.10 [7/64]  | 4426 | 14- 6.25 [1/4]   |
| 3947 | 12-11.39 [25/64] | 4027 | 13- 2.54 [35/64] | 4107 | 13- 5.69 [11/16] | 4187 | 13- 8.84 [27/32] | 4267 | 13-11.99 [63/64] | 4347 | 14- 3.14 [9/64]  | 4427 | 14- 6.29 [19/64] |
| 3948 | 12-11.43 [7/16]  | 4028 | 13- 2.58 [37/64] | 4108 | 13- 5.73 [47/64] | 4188 | 13- 8.88 [7/8]   | 4268 | 14- 0.03 [1/32]  | 4348 | 14- 3.18 [3/16]  | 4428 | 14- 6.33 [21/64] |
| 3949 | 12-11.47 [15/32] | 4029 | 13- 2.62 [5/8]   | 4109 | 13- 5.77 [49/64] | 4189 | 13- 8.92 [59/64] | 4269 | 14- 0.07 [5/64]  | 4349 | 14- 3.22 [7/32]  | 4429 | 14- 6.37 [3/8]   |
| 3950 | 12-11.51 [33/64] | 4030 | 13- 2.66 [21/32] | 4110 | 13- 5.81 [13/16] | 4190 | 13- 8.96 [61/64] | 4270 | 14- 0.11 [7/64]  | 4350 | 14- 3.26 [17/64] | 4430 | 14- 6.41 [13/32] |
| 3951 | 12-11.55 [35/64] | 4031 | 13- 2.70 [45/64] | 4111 | 13- 5.85 [27/32] | 4191 | 13- 9.00         | 4271 | 14- 0.15 [5/32]  | 4351 | 14- 3.30 [19/64] | 4431 | 14- 6.45 [29/64] |
| 3952 | 12-11.59 [19/32] | 4032 | 13- 2.74 [47/64] | 4112 | 13- 5.89 [57/64] | 4192 | 13- 9.04 [3/64]  | 4272 | 14- 0.19 [3/16]  | 4352 | 14- 3.34 [11/32] | 4432 | 14- 6.49 [31/64] |
| 3953 | 12-11.63 [5/8]   | 4033 | 13- 2.78 [25/32] | 4113 | 13- 5.93 [59/64] | 4193 | 13- 9.08 [5/64]  | 4273 | 14- 0.23 [15/64] | 4353 | 14- 3.38 [3/8]   | 4433 | 14- 6.53 [17/32] |
| 3954 | 12-11.67 [43/64] | 4034 | 13- 2.82 [13/16] | 4114 | 13- 5.97 [31/32] | 4194 | 13- 9.12 [1/8]   | 4274 | 14- 0.27 [17/64] | 4354 | 14- 3.42 [27/64] | 4434 | 14- 6.57 [9/16]  |
| 3955 | 12-11.71 [45/64] | 4035 | 13- 2.86 [55/64] | 4115 | 13- 6.01 [1/64]  | 4195 | 13- 9.16 [5/32]  | 4275 | 14- 0.31 [5/16]  | 4355 | 14- 3.46 [29/64] | 4435 | 14- 6.61 [39/64] |
| 3956 | 12-11.75 [3/4]   | 4036 | 13- 2.90 [57/64] | 4116 | 13- 6.05 [3/64]  | 4196 | 13- 9.20 [13/64] | 4276 | 14- 0.35 [11/32] | 4356 | 14- 3.50 [1/2]   | 4436 | 14- 6.65 [41/64] |
| 3957 | 12-11.79 [25/32] | 4037 | 13- 2.94 [15/16] | 4117 | 13- 6.09 [3/32]  | 4197 | 13- 9.24 [15/64] | 4277 | 14- 0.39 [25/64] | 4357 | 14- 3.54 [17/32] | 4437 | 14- 6.69 [11/16] |
| 3958 | 12-11.83 [53/64] | 4038 | 13- 2.98 [31/32] | 4118 | 13- 6.13 [1/8]   | 4198 | 13- 9.28 [9/32]  | 4278 | 14- 0.43 [27/64] | 4358 | 14- 3.57 [37/64] | 4438 | 14- 6.72 [23/32] |
| 3959 | 12-11.87 [55/64] | 4039 | 13- 3.02 [1/64]  | 4119 | 13- 6.17 [11/64] | 4199 | 13- 9.31 [5/16]  | 4279 | 14- 0.46 [15/32] | 4359 | 14- 3.61 [39/64] | 4439 | 14- 6.76 [49/64] |
| 3960 | 12-11.91 [29/32] | 4040 | 13- 3.06 [1/16]  | 4120 | 13- 6.20 [13/64] | 4200 | 13- 9.35 [23/64] | 4280 | 14- 0.50 [1/2]   | 4360 | 14- 3.65 [21/32] | 4440 | 14- 6.80 [51/64] |
| 3961 | 12-11.94 [15/16] | 4041 | 13- 3.09 [3/32]  | 4121 | 13- 6.24 [1/4]   | 4201 | 13- 9.39 [25/64] | 4281 | 14- 0.54 [35/64] | 4361 | 14- 3.69 [11/16] | 4441 | 14- 6.84 [27/32] |
| 3962 | 12-11.98 [63/64] | 4042 | 13- 3.13 [9/64]  | 4122 | 13- 6.28 [9/32]  | 4202 | 13- 9.43 [7/16]  | 4282 | 14- 0.58 [37/64] | 4362 | 14- 3.73 [47/64] | 4442 | 14- 6.88 [7/8]   |
| 3963 | 13- 0.02 [1/32]  | 4043 | 13- 3.17 [11/64] | 4123 | 13- 6.32 [21/64] | 4203 | 13- 9.47 [15/32] | 4283 | 14- 0.62 [5/8]   | 4363 | 14- 3.77 [49/64] | 4443 | 14- 6.92 [59/64] |
| 3964 | 13- 0.06 [1/16]  | 4044 | 13- 3.21 [7/32]  | 4124 | 13- 6.36 [23/64] | 4204 | 13- 9.51 [33/64] | 4284 | 14- 0.66 [21/32] | 4364 | 14- 3.81 [13/16] | 4444 | 14- 6.96 [61/64] |
| 3965 | 13- 0.10 [7/64]  | 4045 | 13- 3.25 [1/4]   | 4125 | 13- 6.40 [13/32] | 4205 | 13- 9.55 [35/64] | 4285 | 14- 0.70 [45/64] | 4365 | 14- 3.85 [27/32] | 4445 | 14- 7.00         |
| 3966 | 13- 0.14 [9/64]  | 4046 | 13- 3.29 [19/64] | 4126 | 13- 6.44 [7/16]  | 4206 | 13- 9.59 [19/32] | 4286 | 14- 0.74 [47/64] | 4366 | 14- 3.89 [57/64] | 4446 | 14- 7.04 [3/64]  |
| 3967 | 13- 0.18 [31/64] | 4047 | 13- 3.33 [21/64] | 4127 | 13- 6.48 [31/64] | 4207 | 13- 9.63 [5/8]   | 4287 | 14- 0.78 [25/32] | 4367 | 14- 3.93 [59/64] | 4447 | 14- 7.08 [5/64]  |
| 3968 | 13- 0.22 [7/32]  | 4048 | 13- 3.37 [3/8]   | 4128 | 13- 6.52 [33/64] | 4208 | 13- 9.67 [43/64] | 4288 | 14- 0.82 [13/16] | 4368 | 14- 3.97 [31/32] | 4448 | 14- 7.12 [1/8]   |
| 3969 | 13- 0.26 [17/64] | 4049 | 13- 3.41 [13/32] | 4129 | 13- 6.56 [9/16]  | 4209 | 13- 9.71 [45/64] | 4289 | 14- 0.86 [55/64] | 4369 | 14- 4.01 [1/64]  | 4449 | 14- 7.16 [5/32]  |
| 3970 | 13- 0.30 [19/64] | 4050 | 13- 3.45 [29/64] | 4130 | 13- 6.60 [19/32] | 4210 | 13- 9.75 [3/4]   | 4290 | 14- 0.90 [57/64] | 4370 | 14- 4.05 [3/64]  | 4450 | 14- 7.20 [13/64] |
| 3971 | 13- 0.34 [11/32] | 4051 | 13- 3.49 [31/64] | 4131 | 13- 6.64 [41/64] | 4211 | 13- 9.79 [25/32] | 4291 | 14- 0.94 [15/16] | 4371 | 14- 4.09 [3/32]  | 4451 | 14- 7.24 [15/64] |
| 3972 | 13- 0.38 [3/8]   | 4052 | 13- 3.53 [17/32] | 4132 | 13- 6.68 [43/64] | 4212 | 13- 9.83 [53/64] | 4292 | 14- 0.98 [31/32] | 4372 | 14- 4.13 [1/8]   | 4452 | 14- 7.28 [9/32]  |
| 3973 | 13- 0.42 [27/64] | 4053 | 13- 3.57 [9/16]  | 4133 | 13- 6.72 [23/32] | 4213 | 13- 9.87 [55/64] | 4293 | 14- 1.02 [1/64]  | 4373 | 14- 4.17 [11/64] | 4453 | 14- 7.31 [5/16]  |
| 3974 | 13- 0.46 [29/64] | 4054 | 13- 3.61 [39/64] | 4134 | 13- 6.76 [3/4]   | 4214 | 13- 9.91 [29/32] | 4294 | 14- 1.06 [1/16]  | 4374 | 14- 4.20 [13/64] | 4454 | 14- 7.35 [21/64] |
| 3975 | 13- 0.50 [1/2]   | 4055 | 13- 3.65 [41/64] | 4135 | 13- 6.80 [51/64] | 4215 | 13- 9.94 [15/16] | 4295 | 14- 1.09 [3/32]  | 4375 | 14- 4.24 [1/4]   | 4455 | 14- 7.39 [25/64] |
| 3976 | 13- 0.54 [17/32] | 4056 | 13- 3.69 [11/16] | 4136 | 13- 6.83 [53/64] | 4216 | 13- 9.98 [63/64] | 4296 | 14- 1.13 [9/64]  | 4376 | 14- 4.28 [9/32]  | 4456 | 14- 7.43 [7/16]  |
| 3977 | 13- 0.57 [37/64] | 4057 | 13- 3.72 [23/32] | 4137 | 13- 6.87 [7/8]   | 4217 | 13-10.02 [1/32]  | 4297 | 14- 1.17 [11/64] | 4377 | 14- 4.32 [21/64] | 4457 | 14- 7.47 [15/32] |
| 3978 | 13- 0.61 [39/64] | 4058 | 13- 3.76 [49/64] | 4138 | 13- 6.91 [29/32] | 4218 | 13-10.06 [1/16]  | 4298 | 14- 1.21 [7/32]  | 4378 | 14- 4.36 [23/64] | 4458 | 14- 7.51 [33/64] |
| 3979 | 13- 0.65 [21/32] | 4059 | 13- 3.80 [51/64] | 4139 | 13- 6.95 [61/64] | 4219 | 13-10.10 [7/64]  | 4299 | 14- 1.25 [1/4]   | 4379 | 14- 4.40 [13/32] | 4459 | 14- 7.55 [35/64] |
| 3980 | 13- 0.69 [11/16] | 4060 | 13- 3.84 [27/32] | 4140 | 13- 6.99 [63/64] | 4220 | 13-10.14 [9/64]  | 4300 | 14- 1.29 [19/64] | 4380 | 14- 4.44 [7/16]  | 4460 | 14- 7.59 [19/32] |
| 3981 | 13- 0.73 [47/64] | 4061 | 13- 3.88 [7/8]   | 4141 | 13- 7.03 [1/32]  | 4221 | 13-10.18 [3/16]  | 4301 | 14- 1.33 [21/64] | 4381 | 14- 4.48 [31/64] | 4461 | 14- 7.63 [5/8]   |
| 3982 | 13- 0.77 [49/64] | 4062 | 13- 3.92 [59/64] | 4142 | 13- 7.07 [5/64]  | 4222 | 13-10.22         |      |                  |      |                  |      |                  |

# MILLIMETERS CONVERTED TO FEET AND INCHES

# TABLES M-3

| mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) | mm   | ft-in.(fraction) |
|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|
| 4481 | 14- 8.42 [27/64] | 4561 | 14-11.57 [9/16]  | 4641 | 15- 2.72 [23/32] | 4721 | 15- 5.87 [55/64] | 4801 | 15- 9.02 [1/64]  | 4881 | 16- 0.17 [11/64] | 4961 | 16- 3.31 [5/16]  |
| 4482 | 14- 8.46 [29/64] | 4562 | 14-11.61 [39/64] | 4642 | 15- 2.76 [3/4]   | 4722 | 15- 5.91 [29/32] | 4802 | 15- 9.06 [1/16]  | 4882 | 16- 0.20 [13/64] | 4962 | 16- 3.35 [23/64] |
| 4483 | 14- 8.50 [1/2]   | 4563 | 14-11.65 [41/64] | 4643 | 15- 2.80 [51/64] | 4723 | 15- 5.94 [15/16] | 4803 | 15- 9.09 [3/32]  | 4883 | 16- 0.24 [1/4]   | 4963 | 16- 3.39 [25/64] |
| 4484 | 14- 8.54 [17/32] | 4564 | 14-11.69 [11/16] | 4644 | 15- 2.83 [53/64] | 4724 | 15- 5.98 [63/64] | 4804 | 15- 9.13 [9/64]  | 4884 | 16- 0.28 [9/32]  | 4964 | 16- 3.43 [7/16]  |
| 4485 | 14- 8.57 [37/64] | 4565 | 14-11.72 [23/32] | 4645 | 15- 2.87 [7/8]   | 4725 | 15- 6.02 [1/32]  | 4805 | 15- 9.17 [11/64] | 4885 | 16- 0.32 [21/64] | 4965 | 16- 3.47 [15/32] |
| 4486 | 14- 8.61 [39/64] | 4566 | 14-11.76 [49/64] | 4646 | 15- 2.91 [29/32] | 4726 | 15- 6.06 [1/16]  | 4806 | 15- 9.21 [7/32]  | 4886 | 16- 0.36 [23/64] | 4966 | 16- 3.51 [33/64] |
| 4487 | 14- 8.65 [21/32] | 4567 | 14-11.80 [51/64] | 4647 | 15- 2.95 [61/64] | 4727 | 15- 6.10 [7/64]  | 4807 | 15- 9.25 [1/4]   | 4887 | 16- 0.40 [13/32] | 4967 | 16- 3.55 [35/64] |
| 4488 | 14- 8.69 [11/16] | 4568 | 14-11.84 [27/32] | 4648 | 15- 2.99 [63/64] | 4728 | 15- 6.14 [9/64]  | 4808 | 15- 9.29 [19/64] | 4888 | 16- 0.44 [7/16]  | 4968 | 16- 3.59 [19/32] |
| 4489 | 14- 8.73 [47/64] | 4569 | 14-11.88 [7/8]   | 4649 | 15- 3.03 [1/32]  | 4729 | 15- 6.18 [3/16]  | 4809 | 15- 9.33 [21/64] | 4889 | 16- 0.48 [53/64] | 4969 | 16- 3.63 [5/8]   |
| 4490 | 14- 8.77 [49/64] | 4570 | 14-11.92 [59/64] | 4650 | 15- 3.07 [5/64]  | 4730 | 15- 6.22 [7/32]  | 4810 | 15- 9.37 [3/8]   | 4890 | 16- 0.52 [33/64] | 4970 | 16- 3.67 [43/64] |
| 4491 | 14- 8.81 [13/16] | 4571 | 14-11.96 [61/64] | 4651 | 15- 3.11 [7/64]  | 4731 | 15- 6.26 [17/64] | 4811 | 15- 9.41 [13/32] | 4891 | 16- 0.56 [9/16]  | 4971 | 16- 3.71 [45/64] |
| 4492 | 14- 8.85 [27/32] | 4572 | 15- 0.00         | 4652 | 15- 3.15 [5/32]  | 4732 | 15- 6.30 [19/64] | 4812 | 15- 9.45 [29/64] | 4892 | 16- 0.60 [19/32] | 4972 | 16- 3.75 [3/4]   |
| 4493 | 14- 8.89 [57/64] | 4573 | 15- 0.04 [3/64]  | 4653 | 15- 3.19 [3/16]  | 4733 | 15- 6.34 [11/32] | 4813 | 15- 9.49 [31/64] | 4893 | 16- 0.64 [41/64] | 4973 | 16- 3.79 [25/32] |
| 4494 | 14- 8.93 [59/64] | 4574 | 15- 0.08 [5/64]  | 4654 | 15- 3.23 [15/64] | 4734 | 15- 6.38 [3/8]   | 4814 | 15- 9.53 [17/32] | 4894 | 16- 0.68 [43/64] | 4974 | 16- 3.83 [53/64] |
| 4495 | 14- 8.97 [31/32] | 4575 | 15- 0.12 [1/8]   | 4655 | 15- 3.27 [1/64]  | 4735 | 15- 6.42 [27/64] | 4815 | 15- 9.57 [9/16]  | 4895 | 16- 0.72 [23/32] | 4975 | 16- 3.87 [55/64] |
| 4496 | 14- 9.01 [1/64]  | 4576 | 15- 0.16 [5/32]  | 4656 | 15- 3.31 [5/16]  | 4736 | 15- 6.46 [29/64] | 4816 | 15- 9.61 [39/64] | 4896 | 16- 0.76 [3/4]   | 4976 | 16- 3.91 [29/32] |
| 4497 | 14- 9.05 [3/64]  | 4577 | 15- 0.20 [13/64] | 4657 | 15- 3.35 [11/32] | 4737 | 15- 6.50 [1/2]   | 4817 | 15- 9.65 [41/64] | 4897 | 16- 0.80 [51/64] | 4977 | 16- 3.94 [15/16] |
| 4498 | 14- 9.09 [3/32]  | 4578 | 15- 0.24 [15/64] | 4658 | 15- 3.39 [25/64] | 4738 | 15- 6.54 [17/32] | 4818 | 15- 9.69 [11/16] | 4898 | 16- 0.84 [53/64] | 4978 | 16- 3.98 [63/64] |
| 4499 | 14- 9.13 [1/8]   | 4579 | 15- 0.28 [9/32]  | 4659 | 15- 3.43 [27/64] | 4739 | 15- 6.57 [37/64] | 4819 | 15- 9.72 [23/32] | 4899 | 16- 0.88 [7/8]   | 4979 | 16- 4.02 [1/32]  |
| 4500 | 14- 9.17 [11/64] | 4580 | 15- 0.31 [5/16]  | 4660 | 15- 3.46 [15/32] | 4740 | 15- 6.61 [39/64] | 4820 | 15- 9.76 [49/64] | 4900 | 16- 0.91 [29/32] | 4980 | 16- 4.06 [1/16]  |
| 4501 | 14- 9.20 [13/64] | 4581 | 15- 0.35 [23/64] | 4661 | 15- 3.50 [1/2]   | 4741 | 15- 6.65 [21/32] | 4821 | 15- 9.80 [51/64] | 4901 | 16- 0.95 [61/64] | 4981 | 16- 4.10 [7/64]  |
| 4502 | 14- 9.24 [1/4]   | 4582 | 15- 0.39 [25/64] | 4662 | 15- 3.54 [35/64] | 4742 | 15- 6.69 [11/16] | 4822 | 15- 9.84 [27/32] | 4902 | 16- 0.99 [63/64] | 4982 | 16- 4.14 [9/64]  |
| 4503 | 14- 9.28 [9/32]  | 4583 | 15- 0.43 [7/16]  | 4663 | 15- 3.58 [37/64] | 4743 | 15- 6.73 [47/64] | 4823 | 15- 9.88 [7/8]   | 4903 | 16- 1.03 [1/32]  | 4983 | 16- 4.18 [3/16]  |
| 4504 | 14- 9.32 [21/64] | 4584 | 15- 0.47 [15/32] | 4664 | 15- 3.62 [5/8]   | 4744 | 15- 6.77 [49/64] | 4824 | 15- 9.92 [59/64] | 4904 | 16- 1.07 [5/64]  | 4984 | 16- 4.22 [7/32]  |
| 4505 | 14- 9.36 [23/64] | 4585 | 15- 0.51 [33/64] | 4665 | 15- 3.66 [21/32] | 4745 | 15- 6.81 [13/16] | 4825 | 15- 9.96 [61/64] | 4905 | 16- 1.11 [7/64]  | 4985 | 16- 4.26 [17/64] |
| 4506 | 14- 9.40 [13/32] | 4586 | 15- 0.55 [35/64] | 4666 | 15- 3.70 [45/64] | 4746 | 15- 6.85 [27/32] | 4826 | 15-10.00         | 4906 | 16- 1.15 [5/32]  | 4986 | 16- 4.30 [19/64] |
| 4507 | 14- 9.44 [7/16]  | 4587 | 15- 0.59 [19/32] | 4667 | 15- 3.74 [47/64] | 4747 | 15- 6.89 [57/64] | 4827 | 15-10.04 [3/64]  | 4907 | 16- 1.19 [3/16]  | 4987 | 16- 4.34 [11/32] |
| 4508 | 14- 9.48 [31/64] | 4588 | 15- 0.63 [5/8]   | 4668 | 15- 3.78 [25/32] | 4748 | 15- 6.93 [59/64] | 4828 | 15-10.08 [5/64]  | 4908 | 16- 1.23 [15/64] | 4988 | 16- 4.38 [3/8]   |
| 4509 | 14- 9.52 [33/64] | 4589 | 15- 0.67 [43/64] | 4669 | 15- 3.82 [13/16] | 4749 | 15- 6.97 [31/32] | 4829 | 15-10.12 [1/8]   | 4909 | 16- 1.27 [17/64] | 4989 | 16- 4.42 [27/64] |
| 4510 | 14- 9.56 [9/16]  | 4590 | 15- 0.71 [45/64] | 4670 | 15- 3.86 [55/64] | 4750 | 15- 7.01 [1/64]  | 4830 | 15-10.16 [5/32]  | 4910 | 16- 1.31 [5/16]  | 4990 | 16- 4.46 [29/64] |
| 4511 | 14- 9.60 [19/32] | 4591 | 15- 0.75 [3/4]   | 4671 | 15- 3.90 [57/64] | 4751 | 15- 7.05 [3/64]  | 4831 | 15-10.20 [13/64] | 4911 | 16- 1.35 [11/32] | 4991 | 16- 4.50 [1/2]   |
| 4512 | 14- 9.64 [41/64] | 4592 | 15- 0.79 [25/32] | 4672 | 15- 3.94 [15/16] | 4752 | 15- 7.09 [3/32]  | 4832 | 15-10.24 [15/64] | 4912 | 16- 1.39 [25/64] | 4992 | 16- 4.54 [17/32] |
| 4513 | 14- 9.68 [43/64] | 4593 | 15- 0.83 [53/64] | 4673 | 15- 3.98 [31/32] | 4753 | 15- 7.13 [1/8]   | 4833 | 15-10.28 [9/32]  | 4913 | 16- 1.43 [27/64] | 4993 | 16- 4.57 [37/64] |
| 4514 | 14- 9.72 [23/32] | 4594 | 15- 0.87 [55/64] | 4674 | 15- 4.02 [1/64]  | 4754 | 15- 7.17 [11/64] | 4834 | 15-10.31 [5/16]  | 4914 | 16- 1.46 [15/32] | 4994 | 16- 4.61 [39/64] |
| 4515 | 14- 9.76 [3/4]   | 4595 | 15- 0.91 [29/32] | 4675 | 15- 4.06 [1/16]  | 4755 | 15- 7.20 [13/64] | 4835 | 15-10.35 [23/64] | 4915 | 16- 1.50 [1/2]   | 4995 | 16- 4.65 [21/32] |
| 4516 | 14- 9.80 [51/64] | 4596 | 15- 0.94 [15/16] | 4676 | 15- 4.09 [3/32]  | 4756 | 15- 7.24 [1/4]   | 4836 | 15-10.39 [25/64] | 4916 | 16- 1.54 [35/64] | 4996 | 16- 4.69 [11/16] |
| 4517 | 14- 9.83 [53/64] | 4597 | 15- 0.98 [63/64] | 4677 | 15- 4.13 [9/64]  | 4757 | 15- 7.28 [9/32]  | 4837 | 15-10.43 [7/16]  | 4917 | 16- 1.58 [37/64] | 4997 | 16- 4.73 [47/64] |
| 4518 | 14- 9.87 [7/8]   | 4598 | 15- 1.02 [1/32]  | 4678 | 15- 4.17 [11/64] | 4758 | 15- 7.32 [21/64] | 4838 | 15-10.47 [15/32] | 4918 | 16- 1.62 [5/8]   | 4998 | 16- 4.77 [49/64] |
| 4519 | 14- 9.91 [29/32] | 4599 | 15- 1.06 [1/16]  | 4679 | 15- 4.21 [7/32]  | 4759 | 15- 7.36 [23/64] | 4839 | 15-10.51 [33/64] | 4919 | 16- 1.66 [21/32] | 4999 | 16- 4.81 [13/16] |
| 4520 | 14- 9.95 [61/64] | 4600 | 15- 1.10 [7/64]  | 4680 | 15- 4.25 [1/4]   | 4760 | 15- 7.40 [13/32] | 4840 | 15-10.55 [35/64] | 4920 | 16- 1.70 [45/64] | 5000 | 16- 4.85 [27/32] |
| 4521 | 14- 9.99 [63/64] | 4601 | 15- 1.14 [9/64]  | 4681 | 15- 4.29 [19/64] | 4761 | 15- 7.44 [7/16]  | 4841 | 15-10.59 [19/32] | 4921 | 16- 1.74 [47/64] | 5001 | 16- 4.89 [57/64] |
| 4522 | 14-10.03 [1/32]  | 4602 | 15- 1.18 [3/16]  | 4682 | 15- 4.33 [21/64] | 4762 | 15- 7.48 [31/64] | 4842 | 15-10.63 [5/8]   | 4922 | 16- 1.78 [25/32] | 5002 | 16- 4.93 [59/64] |
| 4523 | 14-10.07 [5/64]  | 4603 | 15- 1.22 [7/32]  | 4683 | 15- 4.37 [3/8]   | 4763 | 15- 7.52 [33/64] | 4843 | 15-10.67 [43/64] | 4923 | 16- 1.82 [13/16] | 5003 | 16- 4.97 [31/32] |
| 4524 | 14-10.11 [7/64]  | 4604 | 15- 1.26 [17/64] | 4684 | 15- 4.41 [13/32] | 4764 | 15- 7.56 [9/16]  | 4844 | 15-10.71 [45/64] | 4924 | 16- 1.86 [55/64] | 5004 | 16- 5.01 [1/64]  |
| 4525 | 14-10.15 [5/32]  | 4605 | 15- 1.30 [19/64] | 4685 | 15- 4.45 [29/64] | 4765 | 15- 7.60 [19/32] | 4845 | 15-10.75 [3/4]   | 4925 | 16- 1.90 [57/64] | 5005 | 16- 5.05 [3/64]  |
| 4526 | 14-10.19 [3/16]  | 4606 | 15- 1.34 [11/32] | 4686 | 15- 4.49 [31/64] | 4766 | 15- 7.64 [41/64] | 4846 | 15-10.79 [25/32] | 4926 | 16- 1.94 [15/16] | 5006 | 16- 5.09 [3/32]  |
| 4527 | 14-10.23 [15/64] | 4607 | 15- 1.38 [3/8]   | 4687 | 15- 4.53 [17/32] | 4767 | 15- 7.68 [43/64] | 4847 | 15-10.83 [53/64] | 4927 | 16- 1.98 [31/32] | 5007 | 16- 5.13 [1/8]   |
| 4528 | 14-10.27 [17/64] | 4608 | 15- 1.42 [27/64] | 4688 | 15- 4.57 [9/16]  | 4768 | 15- 7.72 [23/32] | 4848 | 15-10.87 [55/64] | 4928 | 16- 2.02 [1/64]  | 5008 | 16- 5.17 [11/64] |
| 4529 | 14-10.31 [5/16]  | 4609 | 15- 1.46 [29/64] | 4689 | 15- 4.61 [39/64] | 4769 | 15- 7.76 [3/4]   | 4849 | 15-10.91 [29/32] | 4929 | 16- 2.06 [1/16]  | 5009 | 16- 5.20 [13/64] |
| 4530 | 14-10.35 [11/32] | 4610 | 15- 1.50 [1/2]   | 4690 | 15- 4.65 [41/64] | 4770 | 15- 7.80 [51/64] | 4850 | 15-10.94 [15/16] | 4930 | 16- 2.09 [3/32]  | 5010 | 16- 5.24 [1/4]   |
| 4531 | 14-10.39 [25/64] | 4611 | 15- 1.54 [17/32] | 4691 | 15- 4.69 [11/16] | 4771 | 15- 7.83 [53/64] | 4851 | 15-10.98 [63/64] | 4931 | 16- 2.13 [9/64]  | 5011 | 16- 5.28 [9/32]  |
| 4532 | 14-10.43 [27/64] | 4612 | 15- 1.57 [37/64] | 4692 | 15- 4.72 [23/32] | 4772 | 15- 7.87 [7/8]   | 4852 | 15-11.02 [1/32]  | 4932 | 16- 2.17 [11/64] | 5012 | 16- 5.32 [21/64] |
| 4533 | 14-10.46 [15/32] | 4613 | 15- 1.61 [39/64] | 4693 | 15- 4.76 [49/64] | 4773 | 15- 7.91 [29/32] | 4853 | 15-11.06 [1/16]  | 4933 | 16- 2.21 [7/32]  | 5013 | 16- 5.36 [23/64] |
| 4534 | 14-10.50 [1/2]   | 4614 | 15- 1.65 [21/32] | 4694 | 15- 4.80 [51/64] | 4774 | 15- 7.95 [61/64] | 4854 | 15-11.10 [7/64]  | 4934 | 16- 2.25 [1/4]   | 5014 | 16- 5.40 [13/32] |
| 4535 | 14-10.54 [35/64] | 4615 | 15- 1.69 [11/16] | 4695 | 15- 4.84 [27/32] | 4775 | 15- 7.99 [63/64] | 4855 | 15-11.14 [9/64]  | 4935 | 16- 2.29 [19/64] | 5015 | 16- 5.44 [7/16]  |
| 4536 | 14-10.58 [37/64] | 4616 | 15- 1.73 [47/64] | 4696 | 15- 4.88 [7/8]   | 4776 | 15- 8.03 [1/32]  | 4856 | 15-11.18 [3/16]  | 4936 | 16- 2.33 [21/64] | 5016 | 16- 5.48 [31/64] |
| 4537 | 14-10.62 [5/8]   | 4617 | 15- 1.77 [49/64] | 4697 | 15- 4.92 [59/64] | 4777 | 15- 8.07 [5/64]  | 4857 | 15-11.22 [7/32]  | 4937 | 16- 2.37 [3/8]   | 5017 | 16- 5.52 [33/64] |
| 4538 | 14-10.66 [21/32] | 4618 | 15- 1.81 [13/16] | 4698 | 15- 4.96 [61/64] | 4778 | 15- 8.11 [7/64]  | 4858 | 15-11.26 [17/64] | 4938 | 16- 2.41 [13/32] | 5018 | 16- 5.56 [9/16]  |
| 4539 | 14-10.70 [45/64] | 4619 | 15- 1.85 [27/32] | 4699 | 15- 5.00         | 4779 | 15- 8.15 [5/32]  | 4859 | 15-11.30 [19/64] | 4939 | 16- 2.45 [29/64] | 5019 | 16- 5.60 [19/32] |
| 4540 | 14-10.74 [47/64] | 4620 | 15- 1.89 [57/64] | 4700 | 15- 5.04 [3/64]  | 4780 | 15- 8.19 [3/16]  | 4860 | 15-11.34 [11/32] | 4940 | 16- 2.49 [31/64] | 5020 | 16- 5.64 [41/64] |
| 4541 | 14-10.78 [25/32] | 4621 | 15- 1.93 [59/64] | 4701 | 15- 5.08 [5/64]  | 4781 | 15- 8.23 [15/64] | 4861 | 15-11.38 [3/8]   | 4941 | 16- 2.53 [17/32] | 5021 | 16- 5.68 [43/64] |
| 4542 | 14-10.82 [13/16] | 4622 | 15- 1.97 [31/32] | 4702 | 15- 5.12 [1/8]   | 4782 | 15- 8.27         |      |                  |      |                  |      |                  |

# CIRCLES: DIAMETER, CIRCUMFERENCE & AREA

# TABLE M-4

| DIAM.<br>IN. | CIRCUM.<br>IN. | AREA<br>SQ. IN. | DIAM.<br>IN. | CIRCUM.<br>IN. | AREA<br>SQ. IN. | DIAM.<br>IN. | CIRCUM.<br>IN. | AREA<br>SQ. IN. | DIAM.<br>IN. | CIRCUM.<br>IN. | AREA<br>SQ. IN. | DIAM.<br>IN. | CIRCUM.<br>IN. | AREA<br>SQ. IN. |
|--------------|----------------|-----------------|--------------|----------------|-----------------|--------------|----------------|-----------------|--------------|----------------|-----------------|--------------|----------------|-----------------|
| 1/4          | .04909         | .00019          | 2 7/8        | 9.0321         | 6.4918          | 7 3/8        | 23.955         | 45.664          | 21           | 65.973         | 346.36          | 37           | 116.239        | 1075.2          |
| 1/2          | .09818         | .00077          | 2 3/4        | 9.2284         | 6.7771          | 7 1/4        | 24.347         | 47.173          | 21 1/4       | 66.759         | 354.66          | 37 1/4       | 117.024        | 1089.8          |
| 3/4          | .14726         | .00173          | 3            | 9.4248         | 7.0686          | 7 1/2        | 24.740         | 48.707          | 21 1/2       | 67.544         | 363.05          | 37 1/2       | 117.810        | 1104.5          |
| 1 1/4        | .19635         | .00307          | 3 1/8        | 9.6211         | 7.3662          | 8            | 25.133         | 50.265          | 21 3/4       | 68.330         | 371.54          | 37 3/4       | 118.596        | 1119.2          |
| 1 1/2        | .29452         | .00690          | 3 1/4        | 9.8175         | 7.6699          | 8 1/8        | 25.525         | 51.849          | 22           | 69.115         | 380.13          | 38           | 119.381        | 1134.1          |
| 1 3/4        | .39270         | .01227          | 3 1/2        | 10.014         | 7.9798          | 8 1/4        | 25.918         | 53.456          | 22 1/4       | 69.900         | 388.82          | 38 1/4       | 120.166        | 1149.1          |
| 2            | .49087         | .01917          | 3 3/4        | 10.210         | 8.2958          | 8 3/8        | 26.311         | 55.088          | 22 1/2       | 70.686         | 397.61          | 38 1/2       | 120.951        | 1164.2          |
| 2 1/4        | .58905         | .02761          | 3 5/8        | 10.407         | 8.6179          | 8 1/2        | 26.704         | 56.745          | 22 3/4       | 71.471         | 406.49          | 38 3/4       | 121.737        | 1179.3          |
| 2 1/2        | .68722         | .03758          | 3 5/4        | 10.603         | 8.9462          | 8 3/4        | 27.096         | 58.426          | 23           | 72.257         | 415.48          | 39           | 122.522        | 1194.6          |
| 2 3/4        | .78540         | .04909          | 3 5/2        | 10.799         | 9.2806          | 8 7/8        | 27.489         | 60.132          | 23 1/4       | 73.042         | 424.56          | 39 1/4       | 123.308        | 1210.0          |
| 3            | .88357         | .06213          | 3 5/8        | 10.996         | 9.6211          | 9            | 27.882         | 61.862          | 23 1/2       | 73.827         | 433.74          | 39 1/2       | 124.093        | 1225.4          |
| 3 1/4        | .98175         | .07670          | 3 5/4        | 11.192         | 9.9678          | 9 1/8        | 28.274         | 63.617          | 23 3/4       | 74.613         | 443.01          | 39 3/4       | 124.878        | 1241.0          |
| 3 1/2        | 1.0799         | .09281          | 3 5/2        | 11.388         | 10.321          | 9 1/4        | 28.667         | 65.397          | 24           | 75.398         | 452.39          | 40           | 125.664        | 1256.6          |
| 3 3/4        | 1.1781         | .11045          | 3 5/8        | 11.585         | 10.680          | 9 1/2        | 29.060         | 67.201          | 24 1/4       | 76.184         | 461.86          | 40 1/4       | 126.449        | 1272.4          |
| 3 5/4        | 1.2763         | .12962          | 3 5/4        | 11.781         | 11.045          | 9 3/4        | 29.452         | 69.029          | 24 1/2       | 76.969         | 471.44          | 40 1/2       | 127.235        | 1288.2          |
| 3 5/2        | 1.3744         | .15033          | 3 5/2        | 11.977         | 11.416          | 9 1/2        | 29.845         | 70.882          | 24 3/4       | 77.754         | 481.11          | 40 3/4       | 128.020        | 1304.2          |
| 4            | 1.4726         | .17257          | 3 5/8        | 12.174         | 11.793          | 9 3/2        | 30.238         | 72.760          | 25           | 78.540         | 490.87          | 41           | 128.805        | 1320.3          |
| 4 1/4        | 1.5708         | .19635          | 3 5/4        | 12.370         | 12.177          | 9 3/4        | 30.631         | 74.662          | 25 1/4       | 79.325         | 500.74          | 41 1/4       | 129.591        | 1336.4          |
| 4 1/2        | 1.6690         | .22166          | 4            | 12.566         | 12.566          | 9 7/8        | 31.023         | 76.589          | 25 1/2       | 80.111         | 510.71          | 41 1/2       | 130.376        | 1352.7          |
| 4 3/4        | 1.7671         | .24850          | 4 1/4        | 12.763         | 12.962          | 10           | 31.416         | 78.540          | 25 3/4       | 80.896         | 520.77          | 41 3/4       | 131.161        | 1369.0          |
| 4 5/4        | 1.8653         | .27688          | 4 1/2        | 12.959         | 13.364          | 10 1/4       | 32.201         | 82.516          | 26           | 81.681         | 530.93          | 42           | 131.947        | 1385.4          |
| 4 5/2        | 1.9635         | .30680          | 4 1/2        | 13.155         | 13.772          | 10 1/2       | 32.987         | 86.590          | 26 1/4       | 82.467         | 541.19          | 42 1/4       | 132.732        | 1402.0          |
| 4 5/8        | 2.0617         | .33824          | 4 1/2        | 13.352         | 14.186          | 10 3/4       | 33.772         | 90.763          | 26 1/2       | 83.252         | 551.55          | 42 1/2       | 133.518        | 1418.6          |
| 4 5/4        | 2.1598         | .37122          | 4 1/2        | 13.548         | 14.607          | 11           | 34.558         | 95.033          | 26 3/4       | 84.038         | 562.00          | 42 3/4       | 134.303        | 1435.4          |
| 4 5/2        | 2.2580         | .40574          | 4 1/2        | 13.744         | 15.033          | 11 1/4       | 35.343         | 99.402          | 27           | 84.823         | 572.56          | 43           | 135.088        | 1452.2          |
| 4 5/8        | 2.3562         | .44179          | 4 1/2        | 13.941         | 15.466          | 11 1/2       | 36.128         | 103.87          | 27 1/4       | 85.608         | 583.21          | 43 1/4       | 135.874        | 1469.1          |
| 4 5/4        | 2.4544         | .47937          | 4 1/2        | 14.137         | 15.904          | 11 3/4       | 36.914         | 108.43          | 27 1/2       | 86.394         | 593.96          | 43 1/2       | 136.659        | 1486.2          |
| 4 5/2        | 2.5525         | .51849          | 4 1/2        | 14.334         | 16.349          | 12           | 37.699         | 113.10          | 27 3/4       | 87.179         | 604.81          | 43 3/4       | 137.445        | 1503.3          |
| 4 5/8        | 2.6507         | .55914          | 4 1/2        | 14.530         | 16.800          | 12 1/4       | 38.485         | 117.86          | 28           | 87.965         | 615.75          | 44           | 138.230        | 1520.5          |
| 4 5/4        | 2.7489         | .60132          | 4 1/2        | 14.726         | 17.257          | 12 1/2       | 39.270         | 122.72          | 28 1/4       | 88.750         | 626.80          | 44 1/4       | 139.015        | 1537.9          |
| 4 5/2        | 2.8471         | .64504          | 4 1/2        | 14.923         | 17.721          | 12 3/4       | 40.055         | 127.68          | 28 1/2       | 89.535         | 637.94          | 44 1/2       | 139.801        | 1555.3          |
| 4 5/8        | 2.9452         | .69029          | 4 1/2        | 15.119         | 18.190          | 13           | 40.841         | 132.73          | 28 3/4       | 90.321         | 649.18          | 44 3/4       | 140.586        | 1572.8          |
| 4 5/4        | 3.0434         | .73708          | 4 1/2        | 15.315         | 18.665          | 13 1/4       | 41.626         | 137.89          | 29           | 91.106         | 660.52          | 45           | 141.372        | 1590.4          |
| 4 5/2        | 3.1416         | .7854           | 4 1/2        | 15.512         | 19.147          | 13 1/2       | 42.412         | 143.14          | 29 1/4       | 91.892         | 671.96          | 45 1/4       | 142.157        | 1608.2          |
| 5            | 3.3379         | .8866           | 5            | 15.708         | 19.635          | 13 3/4       | 43.197         | 148.49          | 29 1/2       | 92.677         | 683.49          | 45 1/2       | 142.942        | 1626.0          |
| 5 1/4        | 3.5343         | .9940           | 5 1/4        | 15.904         | 20.129          | 14           | 43.982         | 153.94          | 29 3/4       | 93.462         | 695.13          | 45 3/4       | 143.728        | 1643.9          |
| 5 1/2        | 3.7306         | 1.1075          | 5 1/4        | 16.101         | 20.629          | 14 1/4       | 44.768         | 159.48          | 30           | 94.248         | 706.86          | 46           | 144.513        | 1661.9          |
| 5 1/4        | 3.9270         | 1.2272          | 5 1/4        | 16.297         | 21.135          | 14 1/2       | 45.553         | 165.13          | 30 1/4       | 95.033         | 718.69          | 46 1/4       | 145.299        | 1680.0          |
| 5 1/2        | 4.1233         | 1.3530          | 5 1/4        | 16.493         | 21.648          | 14 3/4       | 46.338         | 170.87          | 30 1/2       | 95.819         | 730.62          | 46 1/2       | 146.084        | 1698.2          |
| 5 1/4        | 4.3197         | 1.4849          | 5 1/4        | 16.690         | 22.166          | 15           | 47.124         | 176.71          | 30 3/4       | 96.604         | 742.64          | 46 3/4       | 146.869        | 1716.5          |
| 5 1/2        | 4.5160         | 1.6230          | 5 1/4        | 16.886         | 22.691          | 15 1/4       | 47.909         | 182.65          | 31           | 97.389         | 754.77          | 47           | 147.655        | 1734.9          |
| 5 1/4        | 4.7124         | 1.7671          | 5 1/4        | 17.082         | 23.221          | 15 1/2       | 48.695         | 188.69          | 31 1/4       | 98.175         | 766.99          | 47 1/4       | 148.440        | 1753.5          |
| 5 1/2        | 4.9087         | 1.9175          | 5 1/4        | 17.279         | 23.758          | 15 3/4       | 49.480         | 194.83          | 31 1/2       | 98.960         | 779.31          | 47 1/2       | 149.226        | 1772.1          |
| 5 3/4        | 5.1051         | 2.0739          | 5 1/4        | 17.475         | 24.301          | 16           | 50.265         | 201.06          | 31 3/4       | 99.746         | 791.73          | 47 3/4       | 150.011        | 1790.8          |
| 5 5/4        | 5.3014         | 2.2365          | 5 1/4        | 17.671         | 24.850          | 16 1/4       | 51.051         | 207.39          | 32           | 100.531        | 804.25          | 48           | 150.796        | 1809.6          |
| 5 5/2        | 5.4978         | 2.4053          | 5 1/4        | 17.868         | 25.406          | 16 1/2       | 51.836         | 213.82          | 32 1/4       | 101.316        | 816.86          | 48 1/4       | 151.582        | 1828.5          |
| 5 5/4        | 5.6941         | 2.5802          | 5 1/4        | 18.064         | 25.967          | 16 3/4       | 52.622         | 220.35          | 32 1/2       | 102.102        | 829.58          | 48 1/2       | 152.367        | 1847.5          |
| 5 5/2        | 5.8905         | 2.7612          | 5 1/4        | 18.261         | 26.535          | 17           | 53.407         | 226.98          | 32 3/4       | 102.887        | 842.39          | 48 3/4       | 153.153        | 1866.5          |
| 5 5/4        | 6.0868         | 2.9483          | 5 1/4        | 18.457         | 27.109          | 17 1/4       | 54.192         | 233.71          | 33           | 103.673        | 855.30          | 49           | 153.938        | 1885.7          |
| 6            | 6.2832         | 3.1416          | 5 1/4        | 18.653         | 27.688          | 17 1/2       | 54.978         | 240.53          | 33 1/4       | 104.458        | 868.31          | 49 1/4       | 154.723        | 1905.0          |
| 6 1/4        | 6.4795         | 3.3410          | 6            | 18.850         | 28.274          | 17 3/4       | 55.763         | 247.45          | 33 1/2       | 105.243        | 881.41          | 49 1/2       | 155.509        | 1924.4          |
| 6 1/2        | 6.6759         | 3.5466          | 6            | 19.242         | 29.465          | 18           | 56.549         | 254.47          | 33 3/4       | 106.029        | 894.62          | 49 3/4       | 156.294        | 1943.9          |
| 6 3/4        | 6.8722         | 3.7583          | 6            | 19.635         | 30.680          | 18 1/4       | 57.334         | 261.59          | 34           | 106.814        | 907.92          | 50           | 157.080        | 1963.5          |
| 6 5/4        | 7.0686         | 3.9761          | 6            | 20.028         | 31.919          | 18 1/2       | 58.119         | 268.80          | 34 1/4       | 107.600        | 921.32          | 50 1/4       | 157.865        | 1983.2          |
| 6 5/2        | 7.2649         | 4.2000          | 6            | 20.420         | 33.183          | 18 3/4       | 58.905         | 276.12          | 34 1/2       | 108.385        | 934.82          | 50 1/2       | 158.650        | 2003.0          |
| 6 5/4        | 7.4613         | 4.4301          | 6            | 20.813         | 34.472          | 19           | 59.690         | 283.53          | 34 3/4       | 109.170        | 948.42          | 50 3/4       | 159.436        | 2022.8          |
| 6 5/2        | 7.6576         | 4.6664          | 6            | 21.206         | 35.785          | 19 1/4       | 60.476         | 291.04          | 35           | 109.956        | 962.11          | 51           | 160.221        | 2042.8          |
| 6 5/4        | 7.8540         | 4.9087          | 6            | 21.598         | 37.122          | 19 1/2       | 61.261         | 298.65          | 35 1/4       | 110.741        | 975.91          | 51 1/4       | 161.007        | 2062.9          |
| 6 5/2        | 8.0503         | 5.1572          | 7            | 21.991         | 38.485          | 19 3/4       | 62.046         | 306.35          | 35 1/2       | 111.527        | 989.80          | 51 1/2       | 161.792        | 2083.1          |
| 6 5/4        | 8.2467         | 5.4119          | 7 1/4        | 22.384         | 39.871          | 20           | 62.832         | 314.16          | 35 3/4       | 112.312        | 1003.80         | 51 3/4       | 162.577        | 2103.3          |
| 6 5/2        | 8.4430         | 5.6727          | 7 1/2        | 22.776         | 41.282          | 20 1/4       | 63.617         | 322.06          | 36           | 113.097        | 1017.90         | 52           | 163.363        | 2123.7          |
| 6 5/4        | 8.6394         | 5.9396          | 7 3/8        | 23.169         | 42.718          | 20 1/2       | 64.403         | 330.06          | 36 1/4       | 113.883        | 1032.10         | 52 1/4       | 164.148        | 2144.2          |
| 6 5/2        | 8.8357         | 6.2126          | 7 3/4        | 23.562         | 44.179          | 20 3/4       | 65.188         | 338.16          | 36 1/2       | 114.668        | 1046.30         | 52 1/2       | 164.934        | 2164.8          |

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# DECIMALS OF AN INCH & OF A FOOT

# TABLE M-5

| FRACTIONS OF AN INCH | DECIMAL EQUIVALENTS       | FRACTIONS OF A FOOT                               | FRACTIONS OF AN INCH | DECIMAL EQUIVALENTS       | FRACTIONS OF A FOOT                               | FRACTIONS OF AN INCH | DECIMAL EQUIVALENTS       | FRACTIONS OF A FOOT                               | FRACTIONS OF AN INCH | DECIMAL EQUIVALENTS       | FRACTIONS OF A FOOT                                  |
|----------------------|---------------------------|---|----------------------|---------------------------|---|----------------------|---------------------------|---|----------------------|---------------------------|--|
|                      | .0052<br>.0104            | $\frac{1}{16}$ "<br>$\frac{1}{8}$                 |                      | .2552<br>.2604            | $\frac{3}{16}$ "<br>$\frac{3}{8}$                 |                      | .5052<br>.5104            | $\frac{6}{16}$ "<br>$\frac{6}{8}$                 |                      | .7552<br>.7604            | $\frac{9}{16}$ "<br>$\frac{9}{8}$                    |
| $\frac{1}{64}$       | .015625<br>.0208<br>.0260 | $\frac{3}{16}$<br>$\frac{1}{4}$<br>$\frac{5}{16}$ | $\frac{1}{64}$       | .265625<br>.2708<br>.2760 | $\frac{3}{16}$<br>$\frac{3}{4}$<br>$\frac{3}{16}$ | $\frac{3}{64}$       | .515625<br>.5208<br>.5260 | $\frac{6}{16}$<br>$\frac{6}{4}$<br>$\frac{6}{16}$ | $\frac{4}{64}$       | .765625<br>.7708<br>.7760 | $\frac{9}{16}$<br>$\frac{9}{4}$<br>$\frac{9}{16}$    |
| $\frac{1}{32}$       | .03125<br>.0365<br>.0417  | $\frac{3}{8}$<br>$\frac{7}{16}$<br>$\frac{1}{2}$  | $\frac{9}{32}$       | .28125<br>.2865<br>.2917  | $\frac{3}{8}$<br>$\frac{3}{16}$<br>$\frac{3}{2}$  | $\frac{1}{32}$       | .53125<br>.5365<br>.5417  | $\frac{6}{8}$<br>$\frac{6}{16}$<br>$\frac{6}{2}$  | $\frac{2}{32}$       | .78125<br>.7865<br>.7917  | $\frac{9}{8}$<br>$\frac{9}{16}$<br>$\frac{9}{2}$     |
| $\frac{3}{64}$       | .046875<br>.0521<br>.0573 | $\frac{9}{16}$<br>$\frac{5}{8}$<br>$\frac{1}{16}$ | $\frac{1}{64}$       | .296875<br>.3021<br>.3073 | $\frac{3}{16}$<br>$\frac{3}{8}$<br>$\frac{3}{16}$ | $\frac{3}{64}$       | .546875<br>.5521<br>.5573 | $\frac{6}{16}$<br>$\frac{6}{8}$<br>$\frac{6}{16}$ | $\frac{5}{64}$       | .796875<br>.8021<br>.8073 | $\frac{9}{16}$<br>$\frac{9}{8}$<br>$\frac{9}{16}$    |
| $\frac{1}{16}$       | .0625<br>.0677<br>.0729   | $\frac{3}{4}$<br>$\frac{1}{2}$<br>$\frac{3}{8}$   | $\frac{5}{16}$       | .3125<br>.3177<br>.3229   | $\frac{3}{4}$<br>$\frac{3}{16}$<br>$\frac{3}{8}$  | $\frac{9}{16}$       | .5625<br>.5677<br>.5729   | $\frac{6}{4}$<br>$\frac{6}{16}$<br>$\frac{6}{8}$  | $\frac{1}{16}$       | .8125<br>.8177<br>.8229   | $\frac{9}{4}$<br>$\frac{9}{16}$<br>$\frac{9}{8}$     |
| $\frac{5}{64}$       | .078125<br>.0833<br>.0885 | $\frac{1}{2}$<br>1<br>$\frac{1}{16}$              | $\frac{2}{64}$       | .328125<br>.3333<br>.3385 | $\frac{3}{16}$<br>4<br>$\frac{4}{16}$             | $\frac{3}{64}$       | .578125<br>.5833<br>.5885 | $\frac{6}{16}$<br>7<br>$\frac{7}{16}$             | $\frac{5}{64}$       | .828125<br>.8333<br>.8385 | $\frac{9}{16}$<br>10<br>$\frac{10}{16}$              |
| $\frac{3}{32}$       | .09375<br>.0990<br>.1042  | $\frac{1}{8}$<br>$\frac{1}{4}$<br>$\frac{1}{4}$   | $\frac{1}{32}$       | .34375<br>.3490<br>.3542  | $\frac{4}{8}$<br>$\frac{4}{16}$<br>$\frac{4}{4}$  | $\frac{1}{32}$       | .59375<br>.5990<br>.6042  | $\frac{7}{8}$<br>$\frac{7}{16}$<br>$\frac{7}{4}$  | $\frac{2}{32}$       | .84375<br>.8490<br>.8542  | $\frac{10}{8}$<br>$\frac{10}{16}$<br>$\frac{10}{4}$  |
| $\frac{7}{64}$       | .109375<br>.1146<br>.1198 | $\frac{1}{2}$<br>$\frac{1}{8}$<br>$\frac{1}{16}$  | $\frac{2}{64}$       | .359375<br>.3646<br>.3698 | $\frac{4}{16}$<br>$\frac{4}{8}$<br>$\frac{4}{16}$ | $\frac{3}{64}$       | .609375<br>.6146<br>.6198 | $\frac{7}{16}$<br>$\frac{7}{8}$<br>$\frac{7}{16}$ | $\frac{5}{64}$       | .859375<br>.8646<br>.8698 | $\frac{10}{16}$<br>$\frac{10}{8}$<br>$\frac{10}{16}$ |
| $\frac{1}{8}$        | .1250<br>.1302<br>.1354   | $\frac{1}{2}$<br>$\frac{1}{4}$<br>$\frac{1}{8}$   | $\frac{3}{8}$        | .3750<br>.3802<br>.3854   | $\frac{4}{2}$<br>$\frac{4}{16}$<br>$\frac{4}{8}$  | $\frac{5}{8}$        | .6250<br>.6302<br>.6354   | $\frac{7}{2}$<br>$\frac{7}{16}$<br>$\frac{7}{8}$  | $\frac{7}{8}$        | .8750<br>.8802<br>.8854   | $\frac{10}{2}$<br>$\frac{10}{16}$<br>$\frac{10}{8}$  |
| $\frac{9}{64}$       | .140625<br>.1458<br>.1510 | $\frac{1}{2}$<br>$\frac{1}{4}$<br>$\frac{1}{16}$  | $\frac{2}{64}$       | .390625<br>.3958<br>.4010 | $\frac{4}{16}$<br>$\frac{4}{4}$<br>$\frac{4}{16}$ | $\frac{4}{64}$       | .640625<br>.6458<br>.6510 | $\frac{7}{16}$<br>$\frac{7}{4}$<br>$\frac{7}{16}$ | $\frac{5}{64}$       | .890625<br>.8958<br>.9010 | $\frac{10}{16}$<br>$\frac{10}{4}$<br>$\frac{10}{16}$ |
| $\frac{5}{32}$       | .15625<br>.1615<br>.1667  | $\frac{1}{8}$<br>$\frac{1}{16}$<br>2              | $\frac{1}{32}$       | .40625<br>.4115<br>.4167  | $\frac{4}{8}$<br>$\frac{4}{16}$<br>5              | $\frac{2}{32}$       | .65625<br>.6615<br>.6667  | $\frac{7}{8}$<br>$\frac{7}{16}$<br>8              | $\frac{2}{32}$       | .90625<br>.9115<br>.9167  | $\frac{10}{8}$<br>$\frac{10}{16}$<br>11              |
| $\frac{1}{16}$       | .171875<br>.1771<br>.1823 | $\frac{2}{16}$<br>$\frac{2}{8}$<br>$\frac{2}{16}$ | $\frac{2}{64}$       | .421875<br>.4271<br>.4328 | $\frac{5}{16}$<br>$\frac{5}{8}$<br>$\frac{5}{16}$ | $\frac{4}{64}$       | .671875<br>.6771<br>.6823 | $\frac{8}{16}$<br>$\frac{8}{8}$<br>$\frac{8}{16}$ | $\frac{5}{64}$       | .921875<br>.9271<br>.9323 | $\frac{11}{16}$<br>$\frac{11}{8}$<br>$\frac{11}{16}$ |
| $\frac{3}{16}$       | .1875<br>.1927<br>.1979   | $\frac{2}{4}$<br>$\frac{2}{16}$<br>$\frac{2}{8}$  | $\frac{7}{16}$       | .4375<br>.4427<br>.4479   | $\frac{5}{4}$<br>$\frac{5}{16}$<br>$\frac{5}{8}$  | $\frac{1}{16}$       | .6875<br>.6927<br>.6979   | $\frac{8}{4}$<br>$\frac{8}{16}$<br>$\frac{8}{8}$  | $\frac{1}{16}$       | .9375<br>.9427<br>.9479   | $\frac{11}{4}$<br>$\frac{11}{16}$<br>$\frac{11}{8}$  |
| $\frac{1}{8}$        | .203125<br>.2083<br>.2135 | $\frac{2}{16}$<br>$\frac{2}{2}$<br>$\frac{2}{16}$ | $\frac{2}{64}$       | .453125<br>.4583<br>.4635 | $\frac{5}{16}$<br>$\frac{5}{2}$<br>$\frac{5}{16}$ | $\frac{4}{64}$       | .703125<br>.7083<br>.7135 | $\frac{8}{16}$<br>$\frac{8}{2}$<br>$\frac{8}{16}$ | $\frac{6}{64}$       | .953125<br>.9583<br>.9635 | $\frac{11}{16}$<br>$\frac{11}{2}$<br>$\frac{11}{16}$ |
| $\frac{7}{32}$       | .21875<br>.2240<br>.2292  | $\frac{2}{8}$<br>$\frac{2}{16}$<br>$\frac{2}{4}$  | $\frac{1}{32}$       | .46875<br>.4740<br>.4792  | $\frac{5}{8}$<br>$\frac{5}{16}$<br>$\frac{5}{4}$  | $\frac{2}{32}$       | .71875<br>.7240<br>.7292  | $\frac{8}{8}$<br>$\frac{8}{16}$<br>$\frac{8}{4}$  | $\frac{3}{32}$       | .96875<br>.9740<br>.9792  | $\frac{11}{8}$<br>$\frac{11}{16}$<br>$\frac{11}{4}$  |
| $\frac{1}{4}$        | .234375<br>.2396<br>.2448 | $\frac{2}{16}$<br>$\frac{2}{8}$<br>$\frac{2}{16}$ | $\frac{3}{64}$       | .484375<br>.4896<br>.4948 | $\frac{5}{16}$<br>$\frac{5}{8}$<br>$\frac{5}{16}$ | $\frac{4}{64}$       | .734375<br>.7396<br>.7448 | $\frac{8}{16}$<br>$\frac{8}{8}$<br>$\frac{8}{16}$ | $\frac{6}{64}$       | .984375<br>.9896<br>.9948 | $\frac{11}{16}$<br>$\frac{11}{8}$<br>$\frac{11}{16}$ |
| $\frac{1}{4}$        | .2500                     | 3   | $\frac{1}{2}$        | .5000                     | 6   | $\frac{3}{4}$        | .7500                     | 9   | 1                    | 1.000                     | 12   |

### TABLE M-6

Reproduced by courtesy of Jenkins Bros., valve manufacturers. Find the temperature it is required to convert in the center column. If this temperature is in degrees F, the centigrade equivalent is in the left column; if this temperature is in degrees C, the fahrenheit equivalent is in the right column.

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# CONVERSIONS - MULTIPLIERS FOR CUSTOMARY & METRIC UNITS

# TABLE M-7

\* indicates value is exact. Units in pounds are avoirdupois. Abbreviations include: Btu = British thermal unit; C = Centigrade &/or Celsius; Chu = Centigrade heat unit; cu = cubic; EU = European Union; F = Fahrenheit; ft = feet or foot; Hg = Mercury; in = inch(es); k = kelvin; kgf = kilogram-force; lbf = pound-force; liq = liquid; R = Rankine; sq = square; UK = United Kingdom; US = United States.

| MULTIPLY                       | BY  | TO OBTAIN   | MULTIPLY                                 | BY  | TO OBTAIN   |
|--------------------------------|---|---|--|---|---|
| acre                           | 43 560<br>4 840<br>4 046.856 4<br>0.404 685 6<br>0.001 562 5*   | square feet<br>square yards<br>square meters<br>hectare<br>square mile                            | cubic decimeter                          | 1<br>1 000  | liter<br>cubic cm   |
| acre foot                      | 43 560<br>1 233.481 8<br>325 851.43   | cubic feet<br>cubic meters<br>gallons (US)  | cubic inch                               | 16.387 064*<br>0.016 387 064  | cubic cm<br>liter   |
| are [a]                        | 100<br>119.599 01<br>0.024 710 54   | square meters<br>square yards<br>acre   | cubic foot                               | 28 316.846 6<br>0.028 316 85<br>1 728<br>0.037 037 04<br>28.316 846 6<br>7.480 519 5<br>6.228 835 6 | cubic cm<br>cubic meter<br>cubic inches<br>cubic yard<br>liters<br>gallons (US)<br>gallons (UK) |
| atmosphere                     | 1.013 25*<br>101 325*<br>759.999 81<br>29.921 252<br>33.932 447<br>14.695 949                                   | bar<br>pascals<br>mm of Hg @ 32F<br>inches of Hg @ 32F<br>ft of water @ 60F<br>pounds/square inch | cubic ft/acre                            | 0.069 972 3   | cu m/hectare  |
| bar                            | 100 000<br>100 000<br>0.1*<br>14.503 774 1  | pascals<br>newtons/sq meter<br>newton/sq mm<br>pounds/sq inch                                     | cubic foot<br>of water                   | 62.365 578  | pounds @ 15.6C<br>[60F]   |
| barrel [bbl]<br>(petroleum)    | 42<br>5.614 583 3<br>0.158 987 3  | gallons (US)<br>cubic feet<br>cubic meter   | cubic meter                              | 35.314 667<br>1.307 950 6<br>264.172 052<br>1 000<br>2 113.376 42                                   | cubic feet<br>cubic yards<br>gallons (US)<br>liters<br>pints (US)                               |
| Btu                            | 778.169 4<br>107.585 76<br>0.000 293 07<br>(International Table): 1 055.056<br>(thermochemical U.S.): 1 054.350 | foot-pounds<br>kilogram-meters<br>kilowatt-hour<br>joules<br>joules                               | cubic yard                               | 0.764 554 9<br>764.554 86<br>201.974 03   | cubic meter<br>liters<br>gallons(US)  |
| Btu/hour                       | 0.216 158 2<br>0.293 071 1  | foot-pound/second<br>watt   | decimeter [dm]                           | 3.937 007 9<br>100<br>10  | inches<br>millimeters<br>centimeters  |
| bushel [bu]<br>(US)            | 1.244 456<br>0.035 239 07   | cubic feet<br>cubic meter   | degree (angle)                           | 0.017 453 29  | radian  |
| bushel [bu]<br>(UK)            | 1.032 06  | bushels (US)  | dekameter [dam]                          | 10  | meters  |
| cable<br>(US)                  | 120<br>720<br>219.456*  | fathoms<br>feet<br>meters   | fathom                                   | 6<br>1.828 8*   | feet<br>meters  |
| Celsius                        | 1   | Centigrade  | feet/minute                              | 0.005 08*<br>0.304 8*   | meter/second<br>meter/minute  |
| Centigrade                     | 1   | Celsius   | foot                                     | 0.304 8*<br>304.8*<br>12  | meter<br>millimeters<br>inches  |
| centimeter [cm]                | 0.393 700 8<br>10   | inch<br>millimeters   | foot-pound/sec                           | 1.355 817 9   | joules  |
| chain (gunter<br>or surveyors) | 66<br>22<br>20.116 8*   | feet<br>yards<br>meters   | foot (head) of<br>water @ 15.6C<br>[60F] | 2 986.08<br>0.433 094<br>62.365 578   | pascals<br>pound/sq inch<br>pounds/sq foot  |
| Chu (obsolete<br>unit)         | 1.8   | Btu   | furlong                                  | 660<br>201.168*<br>220<br>0.125*  | feet<br>meters<br>yards<br>mile   |
|                                |   |   | gallon (US)<br>-liquid                   | 3.785 411 78<br>3 785.411 78<br>0.003 785 4<br>0.133 680 56   | liters<br>cubic cms<br>cubic meter<br>cubic foot  |

| MULTIPLY                     | BY            | TO OBTAIN                     | MULTIPLY            | BY            | TO OBTAIN          |
|------------------------------|---------------|-------------------------------|---------------------|---------------|--------------------|
|                              | 231           | cubic inches                  | kilometer [km]      | 0.621 371 2   | mile               |
|                              | 8             | pints                         | kilowatt-hour       | 3 412.141 3   | Btu                |
|                              | 4             | quarts                        | liter [L]           | 1 000         | cubic centimeters  |
|                              | 0.832 674 18  | gallon (UK)                   |                     | 1             | cubic decimeter    |
|                              | 8.336 7       | pounds of water @ 15.6C [60F] |                     | 0.001*        | cubic meter        |
| gallon (UK) -liquid          | 1.200 949 9   | gallons (US)                  |                     | 61.023 744 1  | cubic inches       |
|                              | 4.546 09*     | liters                        |                     | 0.035 314 67  | cubic foot         |
|                              | 4.546 09*     | cubic decimeters              |                     | 0.264 172 1   | gallon (liq. US)   |
|                              | 277.419 43    | cubic inches                  |                     | 2.113 376 42  | pints (liq. US)    |
|                              | 8             | pints                         |                     | 33.814 022 7  | fluid ounces (US)  |
|                              | 4             | quarts                        | meter [m]           | 39.370 079    | inches             |
|                              | 10.012        | pounds of water @ 15.6C [60F] |                     | 3.280 839 9   | feet               |
| gram                         | 0.001*        | kilogram                      |                     | 1.093 613 3   | yards              |
|                              | 0.035 273 96  | ounce                         |                     | 0.000 621 4   | mile               |
|                              | 15.432 36     | grains                        |                     | 1 000         | millimeters        |
| gravity: std free fall       | 32.174        | feet/second/second            |                     | 100           | centimeters        |
|                              | 9.806 65*     | m/second/second               |                     | 0.001*        | kilometer          |
| grain                        | 0.064 798 91  | gram                          | micrometer (micron) | 0.001*        | millimeter         |
|                              | 1/700 0       | pound                         |                     | 0.000 039 37  | inch               |
| hectare [ha]                 | 2.471 053 8   | acres                         | mil                 | 0.001*        | inch               |
|                              | 10 000        | square meters                 |                     | 0.025 4*      | millimeter         |
|                              | 107 639.1     | square feet                   |                     | 0.000 025 4*  | meter              |
|                              | 0.003 861     | square mile                   | mile                | 1.609 344*    | kilometers         |
| horsepower                   | 42.407 219    | Btu/minute                    |                     | 1 609.344*    | meters             |
|                              | 2 544.433 1   | Btu/hour                      |                     | 5 280         | feet               |
|                              | 33 000        | foot-pounds/minute            |                     | 1 760         | yards              |
|                              | 550           | foot-pounds/second            |                     | 8             | furlongs           |
|                              | 745.699 87    | watts                         | millimeter [mm]     | 0.1*          | centimeter         |
| horsepower (boiler)          | 33 471.439 8  | Btu/hour                      |                     | 0.001*        | meter              |
|                              | 9 809.5       | watts                         |                     | 0.039 370 79  | inch               |
| horsepower (metric)          | 735.499       | watts                         | newton (N)          | 0.101 971 62  | kilogram-force     |
| horsepower (electric)        | 746           | watts                         |                     | 0.224 808 93  | pound-force        |
| inch                         | 25.4*         | millimeters                   | newton/sq meter     | 1             | pascal             |
|                              | 2.54*         | centimeters                   | ounce               | 28.349 523 12 | grams              |
|                              | 0.025 4*      | meter                         |                     | 0.028 349 5   | kilogram           |
| inch (head) of mercury @ 60F | 1.130 863 9   | feet of water                 |                     | 0.278 013 85  | newton             |
|                              | 3 376.85      | pascals                       | pascal [Pa]         | 1             | newton/sq meter    |
| inch (head) of water @ 60F   | 248.84        | pascals                       |                     | 0.000 145 04  | pound/sq inch      |
| joule [J]                    | 0.000 947 8   | Btu                           | pint                | 16            | fluid ounces (US)  |
|                              | 0.737 562 18  | foot-pound                    |                     | 20            | fluid ounces (UK)  |
|                              | 1             | watt-second                   | pound               | 16            | ounces             |
| kilogram [kg]                | 2.204 623     | pounds                        |                     | 453.592 37*   | grams              |
|                              | 1 000         | grams                         |                     | 0.453 592 37* | kilogram           |
| kgf/sq cm                    | 98 066.5*     | pascals                       |                     | 4.448 221 615 | newtons            |
|                              | 14.223 344    | lbf/sq in                     |                     | 7 000         | grains             |
| kip                          | 1 000         | lbf                           | pound/sq in (psi)   | 6 894.757 2   | pascals            |
|                              | 4 448.221 615 | newtons                       |                     | 2.308 966     | ft of water @ 60F  |
| ksi (kip per sq in)          | 6 894 757     | pascals                       |                     | 2.041 772     | inches of Hg @ 60F |
|                              | 6.894 757     | megapascals [MPa]             | pound/sq ft         | 47.880 258    | pascals            |
|                              |               |                               |                     | 4.882 428     | kg/sq meter        |
|                              |               |                               | pounds/cu in        | 27 679.905    | kg/cu meter        |
|                              |               |                               | pounds/cu ft        | 16.018 463    | kg/cubic meter     |
|                              |               |                               | radian [rad]        | 57.295 779    | degrees            |

| MULTIPLY                       | BY   | TO OBTAIN   | MULTIPLY   | BY   | TO OBTAIN   |
|--------------------------------|--|---|--|--|---|
| CONTINUED FROM PREVIOUS PAGE - |  |   |  |  |   |
| rod (survey)                   | 16.5*<br>5.029 2*                                    | feet<br>meters  | ton (metric)<br>or tonne   | 1 000<br>2 204.623<br>0.984 206 5<br>1.102 311 | kilograms<br>pounds<br>long ton (UK)<br>short tons (US) |
| square cm                      | 0.155  | square inch   | ton of refrigeration   | 12 000<br>200<br>3 517                         | Btu/hour<br>Btu/minute<br>watts                         |
| square meter                   | 0.000 247 1<br>1.195 99<br>10.763 9<br>10 000        | acre<br>square yards<br>square feet<br>square centimeters | watt [W]   | 3.412 141 3<br>0.737 562 2<br>1                | Btu/hour<br>foot-pound/sec<br>joule/second              |
| sq kilometer                   | 0.386 102 2<br>247.105 383                           | square mile<br>acres                                      | watt-hour  | 3.412 141 3                                    | Btu   |
| square inch                    | 645.16*  | square millimeters  | yard [yd]  | 0.914 4*                                       | meter   |
| square foot                    | 0.092 903 04*<br>144                                 | square meter<br>square inches                             | <div>TEMPERATURE CONVERSION:</div> <div> Fahrenheit to Celsius C = (F - 32) / 1.8<br/> Celsius to Fahrenheit F = (C x 1.8) + 32<br/> Fahrenheit to kelvin K = (F + 459.67) / 1.8<br/> Celsius to kelvin K = C + 273.15<br/> kelvin to Celsius C = K - 273.15<br/> Rankine to kelvin K = R / 1.8 </div> <div>VISCOSITY:</div> <div> centipoise (dynamic) 0.001 pascal second (Pa s)<br/> centistokes (kinematic) 0.000 001 sq meter per second </div> |  |   |
| square yard                    | 0.836 127 36*  | square meter  |  |  |   |
| square mile                    | 640<br>2.589 988<br>258.998 8                        | acres<br>sq kilometers<br>hectares                        |  |  |   |
| therm:                         | 100 000  | Btu   |  |  |   |
| Europe (EU)                    | 105 506 000  | joules  |  |  |   |
| United States                  | 105 480 400  | joules  |  |  |   |
| ton (short-US, also net ton)   | 907.184 74*<br>2 000<br>0.907 184 74*<br>0.892 857 1 | kilograms<br>pounds<br>metric ton<br>long ton (UK)        |  |  |   |
| ton (long-UK, also gross ton)  | 1 016.046 91<br>2 240<br>1.016 046 91<br>1.12*       | kilograms<br>pounds<br>metric tons<br>short tons (US)     |  |  |   |

Non-SI units: This table contains units combining kilogram in units of force and pressure. In SI, kilogram is the unit of mass, 'newton' is the unit of force, and 'pascal' is the unit of pressure

FROM 1866 TO 1959, THE METER WAS DEFINED AS 39.37-inches. IN 1959, THE U.S. YARD WAS REDEFINED FROM 3600/3937m (0.914 401 828 037m) TO 0.9144m EXACTLY, HOWEVER, DATA FROM GEODETIC SURVEYS WITHIN THE U.S. CONTINUED TO USE THE FOOT DERIVED FROM THE PRE-1959 STANDARD: THE U.S. SURVEY FOOT. THE FOOT DEFINED IN 1959 IS THE INTERNATIONAL FOOT USED IN THIS TABLE, EXCEPT AS NOTED.

#### RULES FOR ROUNDING VALUES

Reference: ASTM E 380

| FIRST DISCARDED DIGIT                                      | LAST RETAINED DIGIT                                |
|--|--|
| If less than 5   | NO CHANGE  |
| Equal to 5 and followed by at least one digit OTHER than 0 | INCREASE BY ONE UNIT                               |
| If greater than 5  |  |
| Equal to 5 and followed ONLY by zeros                      | IF ODD: INCREASE BY ONE UNIT<br>IF EVEN: NO CHANGE |

REFERENCES: US Department of Commerce/National Institute of Standards & Technology; National Aeronautics & Space Administration; American Society for Testing Materials; The American Society of Mechanical Engineers; National Physical Laboratory-UK

# SPECIFIC HEATS - AVERAGE VALUES

TABLE M-8

Units: Btu/lb/°F = 4 186.8J/kg/K

|                |             |                  |              |                       |             |
|----------------|-------------|------------------|--------------|-----------------------|-------------|
| Aluminum       | 0.214       | Glass, wool      | 0.16         | Quartz                | 0.17 - 0.21 |
| Asbestos       | 0.20        | Granite          | 0.19         | Rocksalt              | 0.22        |
| Asphalt        | 0.40        | Graphite         | 0.201        | Rubber                | 0.27 - 0.48 |
| Carbon         | 0.165       | Ice:             |              | Salt, granulated      | 0.21        |
| Carborundum    | 0.16        | @ -112F          | 0.35         | Sand                  | 0.195       |
| Cast iron      | 0.12 - 0.13 | @ -40F           | 0.43         | Sandstone             | 0.22        |
| Cellulose      | 0.37        | @ -4F            | 0.47         | Seawater, sp gr 1.023 | 0.94        |
| Cement, dry    | 0.37        | @ +32F           | 0.49 - 0.50  | Silica                | 0.191       |
| Cement, powder | 0.20        |                  |              | Silicon               | 0.123       |
| Chalk          | 0.215       | Kerosene         | 0.48 - 0.50  | Soda                  | 0.231       |
| Charcoal       | 0.20 - 0.24 | Lead             | 0.031        | Sodium                | 0.295       |
| Chromium       | 0.12        | Limestone        | 0.217        | Steel                 | 0.117       |
| Coal           | 0.24 - 0.37 | Lucite           | 0.35         | Sucrose               | 0.30        |
| Coke           | 0.203       | Magnesia         | 0.20 - 0.22  | Sugar, bulk           | 0.28        |
| Concrete       | 0.19        | Malleable iron   | 0.12         | Stone                 | 0.20        |
| Copper         | 0.092       | Masonry, brick   | 0.20 - 0.22  | Sulfur                | 0.178       |
| Cork           | 0.48        | Mineral wool     | 0.20         | Tar, bituminous       | 0.35        |
| Dowtherm A     | 0.50        | Mercury          | 0.033        | Teflon                | 0.25        |
| Duralumin      | 0.23        | Molybdenum       | 0.06         | Tile                  | 0.15        |
| Earth, dry     | 0.30        | Nickel           | 0.109        | Tin                   | 0.056       |
| Fuel oil:      |             | Nylon            | 0.55         | Tungsten              | 0.04        |
| sp gr 96       | 0.40        | Olive oil        | 0.35 - 0.47  | Water                 | 1.00        |
| sp gr 91       | 0.44        | Paper            | 0.33         | Wood, fir             | 0.65        |
| sp gr 86       | 0.45        | Plaster of Paris | 1.14         | oak                   | 0.57        |
| sp gr 81       | 0.51        | Platinum         | 0.03 - 0.039 | pine                  | 0.467       |
| Glass, plate   | 0.12        | Polythene        | 0.53         | Wood shavings         | 0.52        |
| Glass, pyrex   | 0.20        |                  |              | Zinc                  | 0.095       |

| GASES            | At Constant Pressure | At Constant Volume | GASES          | At Constant Pressure | At Constant Volume |
|------------------|----------------------|--------------------|----------------|----------------------|--------------------|
| Air              | 0.24                 | 0.172              | Iso-butane     | 0.39                 | 0.355              |
| Ammonia          | 0.54                 | 0.422              | Methane        | 0.59                 | 0.446              |
| Argon            | 0.12                 | 0.720              | Nitrogen       | 0.24                 | 0.170              |
| Carbon dioxide   | 0.20                 | 0.150              | Nitrous oxide  | 0.21                 | 0.166              |
| Carbon monoxide  | 0.24                 | 0.172              | Oxygen         | 0.22                 | 0.157              |
| Carbon disulfide | 0.16                 | 0.132              | Steam:         |                      |                    |
| Chlorine         | 0.11                 | 0.082              | @ 1.0 psia     | 0.46                 | 0.349              |
| Ethylene         | 0.40                 | 0.332              | @ 14.7 psia    | 0.47                 | 0.359              |
| Helium           | 1.25                 | 0.75               | @ 150.0 psia   | 0.54                 | 0.421              |
| Hydrogen         | 3.21                 | 2.410              | Sulfur dioxide | 0.15                 | 0.119              |
| Hydrogen sulfide | 0.25                 | 0.189              |                |                      |                    |

Tables P-1 present calculated data as a guide only. Spans are for pipe arranged in pipeways with the following assumptions: Bare pipe - continuous straight run with welded joints and two or more straight spans at each end.

SPANS - calculated with lines full of water and a maximum bending stress of 4 000 PSI

SAG - (deflection) calculated with lines empty (drained condition)

The following factors were not considered in calculating spans for these tables:

Concentrated mechanical loads from flanges, valves, strainers, filters, and other inline equipment - weights of connecting branch lines - torsional loading from thermal movement - sudden reaction from lines(s) discharging contents - vibration - flattening effect of weight of contents in larger liquid filled lines - weight of insulation and pipe covering - weight of ice and snow - wind loads - seismic shock - reduction in wall thickness of pipe from threading or grooving.

DESIGN PRESSURE - calculated per ANSI B31.1 using allowable stress value of 9 000 PSI for seamless carbon steel pipe

BURSTING PRESSURE is approximate, calculated on yield strength of 30 000 PSI

API = American Petroleum Institute's standard 5L, for 'Line pipe'. API pipe sizes; manufacturers' weights: Double-extra-strong (XXS), Extra-strong (XS), and Standard (STD), are included with schedule numbers in standard ANSI B36.10M. Also refer to 2.1.3

## PIPE DATA: DIMENSIONS & STRESS PARAMETERS

## TABLES P-1

| NPS<br>(inch) | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |         |  | DIMENSIONS    |               |               | WEIGHTS          |                        | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(in <sup>4</sup> ) | Section<br>Modulus<br>(in <sup>3</sup> ) | Radius of<br>Gyration<br>(in.) | Continuous Spans |              | Code Pressures   |                    |
|---------------|---|---------|--|---------------|---------------|---------------|------------------|------------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|--------------------------------|------------------|--------------|------------------|--------------------|
|               |   |         |  | O.D.<br>(in.) | I.D.<br>(in.) | Wall<br>(in.) | Empty<br>(lb/ft) | Waterfilled<br>(lb/ft) | External<br>(in <sup>2</sup> /ft) | Internal<br>(in <sup>2</sup> /ft) | Flow<br>(in <sup>2</sup> ) | Metal<br>(in <sup>2</sup> ) |  |  |                                | Span<br>(ft)     | Sag<br>(in.) | Design<br>(kPSI) | Bursting<br>(kPSI) |
| .375          | SCH 40  | STD API |  | .6750         | .4930         | .0910         | .5690            | .6516                  | 25.45                             | 18.59                             | .1909                      | .1670                       | .0073                                      | .0216                                    | .2090                          | 11.5             | .213         | 1.75             | 5.84               |
|               | SCH 80  | XS API  |  | .6750         | .4230         | .1260         | .7406            | .8015                  | 25.45                             | 15.95                             | .1405                      | .2173                       | .0086                                      | .0255                                    | .1991                          | 11.3             | .217         | 2.89             | 9.63               |
| .500          | SCH 40  | STD API |  | .8400         | .6220         | .1090         | .8531            | .9847                  | 31.67                             | 23.45                             | .3039                      | .2503                       | .0171                                      | .0407                                    | .2613                          | 12.9             | .212         | 1.83             | 6.10               |
|               | SCH 80  | XS API  |  | .8400         | .5460         | .1470         | 1.091            | 1.192                  | 31.67                             | 20.58                             | .2341                      | .3200                       | .0201                                      | .0478                                    | .2505                          | 12.7             | .217         | 2.82             | 9.41               |
|               | SCH 160                                       |         |  | .8400         | .4640         | .1880         | 1.312            | 1.386                  | 31.67                             | 17.49                             | .1691                      | .3851                       | .0222                                      | .0528                                    | .2399                          | 12.3             | .213         | 3.99             | 13.3               |
|               |   | XXS API |  | .8400         | .2520         | .2940         | 1.719            | 1.740                  | 31.67                             | 9.500                             | .0499                      | .5043                       | .0242                                      | .0577                                    | .2192                          | 11.5             | .194         | 7.56             | 25.2               |
| .750          | SCH 40  | STD API |  | 1.050         | .8240         | .1130         | 1.134            | 1.365                  | 39.58                             | 31.06                             | .5333                      | .3326                       | .0370                                      | .0705                                    | .3337                          | 14.4             | .203         | 1.33             | 4.42               |
|               | SCH 80  | XS API  |  | 1.050         | .7420         | .1540         | 1.477            | 1.665                  | 39.58                             | 27.97                             | .4324                      | .4335                       | .0448                                      | .0853                                    | .3214                          | 14.3             | .215         | 2.14             | 7.13               |
|               | SCH 160                                       |         |  | 1.050         | .6120         | .2190         | 1.948            | 2.076                  | 39.58                             | 23.07                             | .2942                      | .5717                       | .0528                                      | .1005                                    | .3038                          | 13.9             | .215         | 3.55             | 11.8               |
|               |   | XXS API |  | 1.050         | .4340         | .3080         | 2.447            | 2.511                  | 39.58                             | 16.36                             | .1479                      | .7180                       | .0579                                      | .1103                                    | .2840                          | 13.3             | .203         | 5.77             | 19.2               |
| 1.00          | SCH 40  | STD API |  | 1.315         | 1.049         | .1330         | 1.683            | 2.057                  | 49.57                             | 39.55                             | .8643                      | .4939                       | .0873                                      | .1328                                    | .4205                          | 16.1             | .199         | 1.27             | 4.24               |
|               | SCH 80  | XS API  |  | 1.315         | .9570         | .1790         | 2.177            | 2.489                  | 49.57                             | 36.08                             | .7193                      | .6388                       | .1056                                      | .1606                                    | .4066                          | 16.1             | .213         | 2.00             | 6.66               |
|               | SCH 160                                       |         |  | 1.315         | .8150         | .2500         | 2.851            | 3.077                  | 49.57                             | 30.72                             | .5217                      | .8364                       | .1251                                      | .1903                                    | .3868                          | 15.7             | .216         | 3.21             | 10.7               |
|               |   | XXS API |  | 1.315         | .5990         | .3580         | 3.668            | 3.790                  | 49.57                             | 22.58                             | .2818                      | 1.076                       | .1405                                      | .2136                                    | .3613                          | 15.0             | .206         | 5.29             | 17.6               |
| 1.25          | SCH 40  | STD API |  | 1.660         | 1.380         | .1400         | 2.278            | 2.926                  | 62.58                             | 52.02                             | 1.496                      | .6685                       | .1947                                      | .2346                                    | .5397                          | 17.9             | .187         | 1.02             | 3.40               |
|               | SCH 80  | XS API  |  | 1.660         | 1.278         | .1910         | 3.004            | 3.560                  | 62.58                             | 48.18                             | 1.283                      | .8815                       | .2418                                      | .2913                                    | .5237                          | 18.1             | .207         | 1.64             | 5.47               |
|               | SCH 160                                       |         |  | 1.660         | 1.160         | .2500         | 3.774            | 4.232                  | 62.58                             | 43.73                             | 1.057                      | 1.107                       | .2839                                      | .3420                                    | .5063                          | 18.0             | .216         | 2.40             | 8.00               |
|               |   | XXS API |  | 1.660         | .8960         | .3820         | 5.227            | 5.500                  | 62.58                             | 33.78                             | .6305                      | 1.534                       | .3411                                      | .4110                                    | .4716                          | 17.3             | .212         | 4.29             | 14.3               |
| 1.50          | SCH 40  | STD API |  | 1.900         | 1.610         | .1450         | 2.725            | 3.606                  | 71.63                             | 60.70                             | 2.036                      | .7995                       | .3099                                      | .3262                                    | .6226                          | 19.0             | .179         | .938             | 3.13               |
|               | SCH 80  | XS API  |  | 1.900         | 1.500         | .2000         | 3.640            | 4.405                  | 71.63                             | 56.55                             | 1.767                      | 1.068                       | .3912                                      | .4118                                    | .6052                          | 19.3             | .202         | 1.52             | 5.06               |
|               | SCH 160                                       |         |  | 1.900         | 1.338         | .2810         | 4.871            | 5.480                  | 71.63                             | 50.44                             | 1.406                      | 1.429                       | .4824                                      | .5078                                    | .5810                          | 19.3             | .215         | 2.42             | 8.08               |
|               |   | XXS API |  | 1.900         | 1.100         | .4000         | 6.424            | 6.835                  | 71.63                             | 41.47                             | .9503                      | 1.885                       | .5678                                      | .5977                                    | .5489                          | 18.7             | .215         | 3.89             | 13.0               |
| 2.00          | SCH 40  | STD API |  | 2.375         | 2.067         | .1540         | 3.662            | 5.115                  | 89.54                             | 77.92                             | 3.356                      | 1.075                       | .6657                                      | .5606                                    | .7871                          | 20.9             | .164         | .736             | 2.45               |
|               | SCH 80  | XS API  |  | 2.375         | 1.939         | .2180         | 5.034            | 6.313                  | 89.54                             | 73.10                             | 2.953                      | 1.477                       | .8679                                      | .7309                                    | .7665                          | 21.5             | .193         | 1.26             | 4.22               |
|               |   | API     |  | 2.375         | 1.875         | .2500         | 5.688            | 6.884                  | 89.54                             | 70.69                             | 2.761                      | 1.669                       | .9551                                      | .8043                                    | .7565                          | 21.6             | .202         | 1.54             | 5.13               |
|               | SCH 160                                       |         |  | 2.375         | 1.687         | .3440         | 7.480            | 8.448                  | 89.54                             | 63.60                             | 2.235                      | 2.195                       | 1.164                                      | .9804                                    | .7283                          | 21.5             | .215         | 2.38             | 7.93               |
|               |   | XXS     |  | 2.375         | 1.503         | .4360         | 9.051            | 9.820                  | 89.54                             | 56.66                             | 1.774                      | 2.656                       | 1.311                                      | 1.104                                    | .7027                          | 21.2             | .217         | 3.26             | 10.9               |

Thru NPS 10, wall thicknesses for SCH 40S and SCH 80S stainless steel pipes are the same as for SCH 40 and SCH 80 carbon steel pipes

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# PIPE DATA

# TABLES P-1

| NPS<br>(inch) | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS | DIMENSIONS    |               |               | WEIGHTS          |                        | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(in <sup>4</sup> ) | Section<br>Modulus<br>(in <sup>3</sup> ) | Radius of<br>Gyration<br>(in.) | Continuous Spans |              | Code Pressures   |                    |
|---------------|---|---------------|---------------|---------------|------------------|------------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|--------------------------------|------------------|--------------|------------------|--------------------|
|               |   | O.D.<br>(in.) | I.D.<br>(in.) | Wall<br>(in.) | Empty<br>(lb/ft) | Waterfilled<br>(lb/ft) | External<br>(in <sup>2</sup> /ft) | Internal<br>(in <sup>2</sup> /ft) | Flow<br>(in <sup>2</sup> ) | Metal<br>(in <sup>2</sup> ) |  |  |                                | Span<br>(ft)     | Sag<br>(in.) | Design<br>(kPSI) | Bursting<br>(kPSI) |
| 2.50          | SCH 40 STD API                                | 2.875         | 2.469         | .2030         | 5.807            | 7.881                  | 108.4                             | 93.08                             | 4.788                      | 1.704                       | 1.530                                      | 1.064                                    | .9474                          | 23.2             | .172         | .865             | 2.88               |
|               | SCH 80 XS API                                 | 2.875         | 2.323         | .2760         | 7.680            | 9.515                  | 108.4                             | 87.58                             | 4.238                      | 2.254                       | 1.924                                      | 1.339                                    | .9241                          | 23.7             | .196         | 1.37             | 4.56               |
|               | SCH 160                                       | 2.875         | 2.125         | .3750         | 10.04            | 11.57                  | 108.4                             | 80.11                             | 3.547                      | 2.945                       | 2.353                                      | 1.637                                    | .8938                          | 23.8             | .212         | 2.09             | 6.96               |
|               | XXS API                                       | 2.875         | 1.771         | .5520         | 13.73            | 14.80                  | 108.4                             | 66.77                             | 2.463                      | 4.028                       | 2.871                                      | 1.997                                    | .8442                          | 23.2             | .216         | 3.49             | 11.6               |
| 3.00          | API   | 3.500         | 3.250         | .1250         | 4.517            | 8.109                  | 131.9                             | 122.5                             | 8.296                      | 1.325                       | 1.890                                      | 1.080                                    | 1.194                          | 23.1             | .105         | .286             | .955               |
|               | API   | 3.500         | 3.188         | .1560         | 5.585            | 9.042                  | 131.9                             | 120.2                             | 7.982                      | 1.639                       | 2.296                                      | 1.312                                    | 1.184                          | 24.1             | .127         | .451             | 1.50               |
|               | API   | 3.500         | 3.124         | .1880         | 6.666            | 9.986                  | 131.9                             | 117.8                             | 7.665                      | 1.956                       | 2.691                                      | 1.538                                    | 1.173                          | 24.8             | .146         | .624             | 2.08               |
|               | SCH 40 STD API                                | 3.500         | 3.068         | .2160         | 7.595            | 10.80                  | 131.9                             | 115.7                             | 7.393                      | 2.228                       | 3.017                                      | 1.724                                    | 1.164                          | 25.3             | .159         | .777             | 2.59               |
|               | API   | 3.500         | 3.000         | .2500         | 8.699            | 11.76                  | 131.9                             | 113.1                             | 7.069                      | 2.553                       | 3.390                                      | 1.937                                    | 1.152                          | 25.7             | .173         | .965             | 3.22               |
|               | API   | 3.500         | 2.938         | .2810         | 9.684            | 12.62                  | 131.9                             | 110.8                             | 6.779                      | 2.842                       | 3.709                                      | 2.119                                    | 1.142                          | 25.9             | .183         | 1.14             | 3.80               |
|               | SCH 80 XS API                                 | 3.500         | 2.900         | .3000         | 10.28            | 13.14                  | 131.9                             | 109.3                             | 6.605                      | 3.016                       | 3.894                                      | 2.225                                    | 1.136                          | 26.0             | .188         | 1.25             | 4.16               |
|               | SCH 160                                       | 3.500         | 2.624         | .4380         | 14.36            | 16.70                  | 131.9                             | 98.92                             | 5.408                      | 4.213                       | 5.039                                      | 2.879                                    | 1.094                          | 26.3             | .210         | 2.07             | 6.89               |
|               | XXS API                                       | 3.500         | 2.300         | .6000         | 18.63            | 20.43                  | 131.9                             | 86.71                             | 4.155                      | 5.466                       | 5.993                                      | 3.424                                    | 1.047                          | 25.9             | .217         | 3.10             | 10.3               |
|               | API   | 4.500         | 4.250         | .1250         | 5.855            | 12.00                  | 169.6                             | 160.2                             | 14.19                      | 1.718                       | 4.114                                      | 1.828                                    | 1.547                          | 24.7             | .082         | .141             | .470               |
| 4             | API   | 4.500         | 4.188         | .1560         | 7.255            | 13.22                  | 169.6                             | 157.9                             | 13.78                      | 2.129                       | 5.028                                      | 2.235                                    | 1.537                          | 26.0             | .102         | .267             | .890               |
|               | API   | 4.500         | 4.124         | .1880         | 8.679            | 14.46                  | 169.6                             | 155.5                             | 13.36                      | 2.547                       | 5.930                                      | 2.636                                    | 1.526                          | 27.0             | .121         | .399             | 1.33               |
|               | API   | 4.500         | 4.062         | .2190         | 10.04            | 15.65                  | 169.6                             | 153.1                             | 12.96                      | 2.945                       | 6.765                                      | 3.007                                    | 1.516                          | 27.7             | .136         | .528             | 1.76               |
|               | SCH 40 STD API                                | 4.500         | 4.026         | .2370         | 10.82            | 16.33                  | 169.6                             | 151.8                             | 12.73                      | 3.174                       | 7.233                                      | 3.214                                    | 1.510                          | 28.1             | .144         | .604             | 2.01               |
|               | API   | 4.500         | 4.000         | .2500         | 11.38            | 16.82                  | 169.6                             | 150.8                             | 12.57                      | 3.338                       | 7.563                                      | 3.361                                    | 1.505                          | 28.3             | .149         | .659             | 2.20               |
|               | API   | 4.500         | 3.938         | .2810         | 12.69            | 17.97                  | 169.6                             | 148.5                             | 12.18                      | 3.724                       | 8.324                                      | 3.699                                    | 1.495                          | 28.7             | .161         | .791             | 2.64               |
|               | API   | 4.500         | 3.876         | .3120         | 13.99            | 19.10                  | 169.6                             | 146.1                             | 11.80                      | 4.105                       | 9.050                                      | 4.022                                    | 1.485                          | 29.0             | .170         | .924             | 3.08               |
|               | SCH 80 XS API                                 | 4.500         | 3.826         | .3370         | 15.02            | 20.00                  | 169.6                             | 144.2                             | 11.50                      | 4.407                       | 9.610                                      | 4.271                                    | 1.477                          | 29.2             | .177         | 1.03             | 3.44               |
|               | SCH 160                                       | 4.500         | 3.438         | .5310         | 22.56            | 26.58                  | 169.6                             | 129.6                             | 9.283                      | 6.621                       | 13.27                                      | 5.898                                    | 1.416                          | 29.8             | .208         | 1.91             | 6.38               |
|               | XXS API                                       | 4.500         | 3.152         | .6740         | 27.61            | 30.99                  | 169.6                             | 118.8                             | 7.803                      | 8.101                       | 15.28                                      | 6.793                                    | 1.374                          | 29.6             | .216         | 2.61             | 8.69               |
| 6             | API   | 6.625         | 6.249         | .1880         | 12.96            | 26.24                  | 249.8                             | 235.6                             | 30.67                      | 3.802                       | 19.71                                      | 5.950                                    | 2.277                          | 30.1             | .084         | .214             | .713               |
|               | API   | 6.625         | 6.187         | .2190         | 15.02            | 28.04                  | 249.8                             | 233.2                             | 30.06                      | 4.407                       | 22.63                                      | 6.833                                    | 2.266                          | 31.2             | .098         | .300             | 1.00               |
|               | API   | 6.625         | 6.125         | .2500         | 17.06            | 29.82                  | 249.8                             | 230.9                             | 29.46                      | 5.007                       | 25.47                                      | 7.690                                    | 2.256                          | 32.1             | .111         | .387             | 1.29               |
|               | SCH 40 STD API                                | 6.625         | 6.065         | .2800         | 19.02            | 31.53                  | 249.8                             | 228.6                             | 28.89                      | 5.581                       | 28.14                                      | 8.496                                    | 2.245                          | 32.8             | .122         | .472             | 1.57               |
|               | API   | 6.625         | 6.001         | .3120         | 21.09            | 33.34                  | 249.8                             | 226.2                             | 28.28                      | 6.188                       | 30.90                                      | 9.329                                    | 2.235                          | 33.5             | .133         | .563             | 1.88               |
|               | API   | 6.625         | 5.937         | .3440         | 23.13            | 35.12                  | 249.8                             | 223.8                             | 27.68                      | 6.788                       | 33.57                                      | 10.14                                    | 2.224                          | 34.0             | .142         | .654             | 2.18               |
|               | SCH 80 XS API                                 | 6.625         | 5.761         | .4320         | 28.64            | 39.93                  | 249.8                             | 217.2                             | 26.07                      | 8.405                       | 40.49                                      | 12.22                                    | 2.195                          | 35.0             | .165         | .910             | 3.03               |
|               | SCH 120                                       | 6.625         | 5.501         | .5620         | 36.48            | 46.77                  | 249.8                             | 207.4                             | 23.77                      | 10.70                       | 49.61                                      | 14.98                                    | 2.153                          | 35.8             | .187         | 1.30             | 4.33               |
|               | SCH 160                                       | 6.625         | 5.187         | .7190         | 45.46            | 54.61                  | 249.8                             | 195.5                             | 21.13                      | 13.34                       | 59.03                                      | 17.82                                    | 2.104                          | 36.1             | .204         | 1.79             | 5.95               |
|               | XXS   | 6.625         | 4.897         | .8640         | 53.29            | 61.45                  | 249.8                             | 184.6                             | 18.83                      | 15.64                       | 66.33                                      | 20.02                                    | 2.060                          | 36.1             | .212         | 2.25             | 7.51               |
| 8             | API   | 8.625         | 8.249         | .1880         | 16.98            | 40.12                  | 325.2                             | 311.0                             | 53.44                      | 4.983                       | 44.36                                      | 10.29                                    | 2.984                          | 32.0             | .062         | .143             | .476               |
|               | API   | 8.625         | 8.219         | .2030         | 18.30            | 41.28                  | 325.2                             | 309.8                             | 53.06                      | 5.371                       | 47.65                                      | 11.05                                    | 2.978                          | 32.7             | .068         | .175             | .582               |
|               | API   | 8.625         | 8.187         | .2190         | 19.71            | 42.51                  | 325.2                             | 308.6                             | 52.64                      | 5.783                       | 51.12                                      | 11.85                                    | 2.973                          | 33.4             | .074         | .209             | .695               |
|               | SCH 20  | 8.625         | 8.125         | .2500         | 22.42            | 44.87                  | 325.2                             | 306.3                             | 51.85                      | 6.578                       | 57.72                                      | 13.38                                    | 2.962                          | 34.5             | .086         | .275             | .915               |
|               | SCH 30  | 8.625         | 8.071         | .2770         | 24.76            | 46.91                  | 325.2                             | 304.3                             | 51.16                      | 7.265                       | 63.35                                      | 14.69                                    | 2.953                          | 35.4             | .095         | .332             | 1.11               |
|               | API   | 8.625         | 8.001         | .3120         | 27.77            | 49.54                  | 325.2                             | 301.6                             | 50.28                      | 8.148                       | 70.49                                      | 16.34                                    | 2.941                          | 36.3             | .106         | .408             | 1.36               |
|               | SCH 40 STD API                                | 8.625         | 7.981         | .3220         | 28.62            | 50.29                  | 325.2                             | 300.9                             | 50.03                      | 8.399                       | 72.49                                      | 16.81                                    | 2.938                          | 36.6             | .110         | .430             | 1.43               |
|               | API   | 8.625         | 7.937         | .3440         | 30.50            | 51.92                  | 325.2                             | 299.2                             | 49.48                      | 8.949                       | 76.85                                      | 17.82                                    | 2.930                          | 37.1             | .116         | .477             | 1.59               |
|               | API   | 8.625         | 7.875         | .3750         | 33.12            | 54.21                  | 325.2                             | 296.9                             | 48.71                      | 9.719                       | 82.86                                      | 19.21                                    | 2.920                          | 37.7             | .125         | .545             | 1.82               |
|               | SCH 60  | 8.625         | 7.813         | .4060         | 35.73            | 56.49                  | 325.2                             | 294.5                             | 47.94                      | 10.48                       | 88.74                                      | 20.58                                    | 2.909                          | 38.2             | .133         | .613             | 2.04               |
|               | API   | 8.625         | 7.749         | .4380         | 38.39            | 58.81                  | 325.2                             | 292.1                             | 47.16                      | 11.27                       | 94.66                                      | 21.95                                    | 2.899                          | 38.6             | .140         | .684             | 2.28               |
|               | SCH 80 XS API                                 | 8.625         | 7.625         | .5000         | 43.50            | 63.27                  | 325.2                             | 287.5                             | 45.66                      | 12.76                       | 105.7                                      | 24.51                                    | 2.878                          | 39.4             | .153         | .822             | 2.74               |
|               | SCH 100                                       | 8.625         | 7.437         | .5940         | 51.07            | 69.89                  | 325.2                             | 280.4                             | 43.44                      | 14.99                       | 121.5                                      | 28.17                                    | 2.847                          | 40.2             | .170         | 1.03             | 3.45               |
|               | SCH 120                                       | 8.625         | 7.187         | .7190         | 60.86            | 78.43                  | 325.2                             | 270.9                             | 40.57                      | 17.86                       | 140.7                                      | 32.62                                    | 2.807                          | 40.8             | .186         | 1.32             | 4.41               |
|               | SCH 140                                       | 8.625         | 7.001         | .8120         | 67.92            | 84.59                  | 325.2                             | 263.9                             | 38.50                      | 19.93                       | 153.7                                      | 35.65                                    | 2.777                          | 41.1             | .195         | 1.54             | 5.14               |
|               | XXS API                                       | 8.625         | 6.875         | .8750         | 72.60            | 88.68                  | 325.2                             | 259.2                             | 37.12                      | 21.30                       | 162.0                                      | 37.56                                    | 2.757                          | 41.2             | .200         | 1.69             | 5.65               |
|               | SCH 160                                       | 8.625         | 6.813         | .9060         | 74.88            | 90.66                  | 325.2                             | 256.8                             | 36.46                      | 21.97                       | 165.9                                      | 38.47                                    | 2.748                          | 41.2             | .202         | 1.77             | 5.90               |

Thru NPS 10, wall thicknesses for SCH 40S and SCH 80S stainless steel pipes are the same as for SCH 40 and SCH 80 carbon steel pipes  
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# PIPE DATA

# TABLES P-1

| NPS<br>(inch) | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |         | DIMENSIONS    |               |               | WEIGHTS          |                        | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(in <sup>4</sup> ) | Section<br>Modulus<br>(in <sup>3</sup> ) | Radius of<br>Gyration<br>(in.) | Continuous Spans<br>Span<br>(ft) | Sag<br>(in.) | Code Pressures   |                    |
|---------------|---|---------|---------------|---------------|---------------|------------------|------------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|--------------------------------|----------------------------------|--------------|------------------|--------------------|
|               |   |         | O.D.<br>(in.) | I.D.<br>(in.) | Wall<br>(in.) | Empty<br>(lb/ft) | Waterfilled<br>(lb/ft) | External<br>(in <sup>2</sup> /ft) | Internal<br>(in <sup>2</sup> /ft) | Flow<br>(in <sup>2</sup> ) | Metal<br>(in <sup>2</sup> ) |  |  |                                |                                  |              | Design<br>(kPSI) | Bursting<br>(kPSI) |
| 10            | SCH 20  | API     | 10.75         | 10.37         | .1880         | 21.26            | 57.86                  | 405.3                             | 391.1                             | 84.52                      | 6.238                       | 87.02                                      | 16.19                                    | 3.735                          | 33.5                             | .047         | .098             | .325               |
|               |   | API     | 10.75         | 10.34         | .2030         | 22.92            | 59.31                  | 405.3                             | 390.0                             | 84.04                      | 6.726                       | 93.56                                      | 17.41                                    | 3.730                          | 34.3                             | .052         | .123             | .410               |
|               |   | API     | 10.75         | 10.31         | .2190         | 24.69            | 60.86                  | 405.3                             | 388.8                             | 83.52                      | 7.245                       | 100.5                                      | 18.69                                    | 3.724                          | 35.1                             | .058         | .150             | .500               |
|               |   | API     | 10.75         | 10.25         | .2500         | 28.10            | 63.84                  | 405.3                             | 386.4                             | 82.52                      | 8.247                       | 113.7                                      | 21.16                                    | 3.713                          | 36.4                             | .067         | .203             | .676               |
|               | SCH 30  | API     | 10.75         | 10.19         | .2790         | 31.28            | 66.61                  | 405.3                             | 384.2                             | 81.58                      | 9.178                       | 125.9                                      | 23.42                                    | 3.703                          | 37.5                             | .076         | .252             | .841               |
|               |   | API     | 10.75         | 10.14         | .3070         | 34.33            | 69.27                  | 405.3                             | 382.1                             | 80.69                      | 10.07                       | 137.4                                      | 25.57                                    | 3.694                          | 38.4                             | .084         | .300             | 1.00               |
|               | SCH 40  | API     | 10.75         | 10.06         | .3440         | 38.33            | 72.76                  | 405.3                             | 379.3                             | 79.52                      | 11.25                       | 152.4                                      | 28.35                                    | 3.681                          | 39.5                             | .095         | .364             | 1.21               |
|               |   | STD API | 10.75         | 10.02         | .3650         | 40.58            | 74.73                  | 405.3                             | 377.7                             | 78.85                      | 11.91                       | 160.7                                      | 29.90                                    | 3.674                          | 40.0                             | .100         | .400             | 1.33               |
|               | SCH 60  | API     | 10.75         | 9.874         | .4380         | 48.36            | 81.52                  | 405.3                             | 372.2                             | 76.57                      | 14.19                       | 188.9                                      | 35.15                                    | 3.649                          | 41.5                             | .118         | .528             | 1.76               |
|               |   | XS API  | 10.75         | 9.750         | .5000         | 54.87            | 87.20                  | 405.3                             | 367.6                             | 74.66                      | 16.10                       | 212.0                                      | 39.43                                    | 3.628                          | 42.5                             | .131         | .637             | 2.12               |
|               | SCH 80  | API     | 10.75         | 9.562         | .5940         | 64.59            | 95.68                  | 405.3                             | 360.5                             | 71.81                      | 18.95                       | 245.2                                      | 45.62                                    | 3.597                          | 43.7                             | .149         | .805             | 2.68               |
|               | SCH 100                                       | API     | 10.75         | 9.312         | .7190         | 77.22            | 106.7                  | 405.3                             | 351.1                             | 68.10                      | 22.66                       | 286.4                                      | 53.29                                    | 3.556                          | 44.7                             | .167         | 1.03             | 3.44               |
|               | SCH 120                                       | API     | 10.75         | 9.062         | .8440         | 89.51            | 117.4                  | 405.3                             | 341.6                             | 64.50                      | 26.27                       | 324.5                                      | 60.38                                    | 3.515                          | 45.3                             | .181         | 1.26             | 4.21               |
|               | SCH 140                                       | XXS API | 10.75         | 8.750         | 1.000         | 104.4            | 130.4                  | 405.3                             | 329.9                             | 60.13                      | 30.63                       | 367.8                                      | 68.43                                    | 3.465                          | 45.8                             | .194         | 1.56             | 5.19               |
|               | SCH 160                                       | API     | 10.75         | 8.500         | 1.125         | 115.9            | 140.5                  | 405.3                             | 320.4                             | 56.75                      | 34.02                       | 399.3                                      | 74.29                                    | 3.426                          | 46.0                             | .202         | 1.80             | 6.00               |
| 12            | SCH 20  | API     | 12.75         | 12.34         | .2030         | 27.27            | 79.09                  | 480.7                             | 465.4                             | 119.7                      | 8.002                       | 157.5                                      | 24.71                                    | 4.437                          | 35.3                             | .042         | .104             | .345               |
|               |   | API     | 12.75         | 12.31         | .2190         | 29.38            | 80.94                  | 480.7                             | 464.2                             | 119.1                      | 8.621                       | 169.3                                      | 26.55                                    | 4.431                          | 36.2                             | .046         | .126             | .421               |
|               |   | API     | 12.75         | 12.25         | .2500         | 33.46            | 84.49                  | 480.7                             | 461.8                             | 117.9                      | 9.817                       | 191.8                                      | 30.09                                    | 4.420                          | 37.7                             | .055         | .171             | .569               |
|               |   | API     | 12.75         | 12.19         | .2810         | 37.51            | 88.03                  | 480.7                             | 459.5                             | 116.7                      | 11.01                       | 214.0                                      | 33.57                                    | 4.410                          | 39.1                             | .063         | .215             | .717               |
|               | SCH 30  | API     | 12.75         | 12.13         | .3120         | 41.55            | 91.56                  | 480.7                             | 457.1                             | 115.5                      | 12.19                       | 235.9                                      | 37.00                                    | 4.399                          | 40.2                             | .071         | .260             | .866               |
|               |   | API     | 12.75         | 12.09         | .3300         | 43.88            | 93.59                  | 480.7                             | 455.8                             | 114.8                      | 12.88                       | 248.5                                      | 38.97                                    | 4.393                          | 40.8                             | .076         | .286             | .953               |
|               | SCH 40  | API     | 12.75         | 12.06         | .3440         | 45.69            | 95.17                  | 480.7                             | 454.7                             | 114.3                      | 13.41                       | 258.1                                      | 40.49                                    | 4.388                          | 41.3                             | .080         | .306             | 1.02               |
|               |   | STD API | 12.75         | 12.00         | .3750         | 49.69            | 98.66                  | 480.7                             | 452.4                             | 113.1                      | 14.58                       | 279.3                                      | 43.82                                    | 4.377                          | 42.1                             | .087         | .351             | 1.17               |
|               | SCH 60  | API     | 12.75         | 11.94         | .4060         | 53.66            | 102.1                  | 480.7                             | 450.1                             | 111.9                      | 15.74                       | 300.2                                      | 47.09                                    | 4.367                          | 42.9                             | .094         | .397             | 1.32               |
|               |   | API     | 12.75         | 11.87         | .4380         | 57.74            | 105.7                  | 480.7                             | 447.6                             | 110.7                      | 16.94                       | 321.4                                      | 50.42                                    | 4.356                          | 43.7                             | .101         | .443             | 1.48               |
|               | SCH 80  | XS API  | 12.75         | 11.75         | .5000         | 65.58            | 112.5                  | 480.7                             | 443.0                             | 108.4                      | 19.24                       | 361.5                                      | 56.71                                    | 4.335                          | 44.9                             | .114         | .535             | 1.78               |
|               |   | API     | 12.75         | 11.63         | .5620         | 73.34            | 119.3                  | 480.7                             | 438.3                             | 106.2                      | 21.52                       | 400.4                                      | 62.81                                    | 4.314                          | 45.9                             | .126         | .627             | 2.09               |
|               | SCH 100                                       | API     | 12.75         | 11.50         | .6250         | 81.14            | 126.1                  | 480.7                             | 433.5                             | 103.9                      | 23.81                       | 438.7                                      | 68.81                                    | 4.293                          | 46.7                             | .137         | .721             | 2.40               |
|               |   | API     | 12.75         | 11.37         | .6880         | 88.85            | 132.8                  | 480.7                             | 428.8                             | 101.6                      | 26.07                       | 475.7                                      | 74.62                                    | 4.271                          | 47.4                             | .146         | .816             | 2.72               |
|               | SCH 120                                       | API     | 12.75         | 11.25         | .7500         | 96.36            | 139.4                  | 480.7                             | 424.1                             | 99.40                      | 28.27                       | 510.9                                      | 80.15                                    | 4.251                          | 48.0                             | .155         | .911             | 3.04               |
|               |   | XXS API | 12.75         | 11.06         | .8440         | 107.6            | 149.2                  | 480.7                             | 417.0                             | 96.11                      | 31.57                       | 562.2                                      | 88.19                                    | 4.220                          | 48.6                             | .166         | 1.06             | 3.52               |
|               | SCH 140                                       | API     | 12.75         | 10.75         | 1.000         | 125.8            | 165.1                  | 480.7                             | 405.3                             | 90.76                      | 36.91                       | 641.7                                      | 100.7                                    | 4.169                          | 49.4                             | .181         | 1.30             | 4.33               |
|               | SCH 160                                       | API     | 12.75         | 10.50         | 1.125         | 140.0            | 177.5                  | 480.7                             | 395.8                             | 86.59                      | 41.09                       | 700.6                                      | 109.9                                    | 4.129                          | 49.8                             | .190         | 1.50             | 4.99               |
|               | SCH 160                                       | API     | 12.75         | 10.13         | 1.312         | 160.7            | 195.5                  | 480.7                             | 381.7                             | 80.53                      | 47.14                       | 781.1                                      | 122.5                                    | 4.070                          | 50.1                             | .201         | 1.80             | 6.01               |
| 14            | SCH 10  | API     | 14.00         | 13.58         | .2100         | 31.01            | 93.72                  | 527.8                             | 512.0                             | 144.8                      | 9.098                       | 216.3                                      | 30.90                                    | 4.876                          | 36.3                             | .039         | .103             | .344               |
|               |   | API     | 14.00         | 13.56         | .2190         | 32.31            | 94.87                  | 527.8                             | 511.3                             | 144.5                      | 9.481                       | 225.1                                      | 32.16                                    | 4.873                          | 36.8                             | .041         | .115             | .383               |
|               |   | API     | 14.00         | 13.50         | .2500         | 36.80            | 98.79                  | 527.8                             | 508.9                             | 143.1                      | 10.80                       | 255.3                                      | 36.47                                    | 4.862                          | 38.4                             | .049         | .155             | .518               |
|               |   | API     | 14.00         | 13.44         | .2810         | 41.27            | 102.7                  | 527.8                             | 506.6                             | 141.8                      | 12.11                       | 285.0                                      | 40.72                                    | 4.851                          | 39.8                             | .057         | .196             | .653               |
|               | SCH 20  | API     | 14.00         | 13.38         | .3120         | 45.72            | 106.6                  | 527.8                             | 504.3                             | 140.5                      | 13.42                       | 314.4                                      | 44.91                                    | 4.841                          | 41.1                             | .064         | .236             | .788               |
|               |   | API     | 14.00         | 13.31         | .3440         | 50.30            | 110.6                  | 527.8                             | 501.9                             | 139.2                      | 14.76                       | 344.2                                      | 49.18                                    | 4.830                          | 42.2                             | .072         | .279             | .928               |
|               | SCH 30  | STD API | 14.00         | 13.25         | .3750         | 54.70            | 114.4                  | 527.8                             | 499.5                             | 137.9                      | 16.05                       | 372.8                                      | 53.25                                    | 4.819                          | 43.1                             | .079         | .319             | 1.06               |
|               | SCH 40  | API     | 14.00         | 13.12         | .4380         | 63.60            | 122.2                  | 527.8                             | 494.8                             | 135.3                      | 18.66                       | 429.5                                      | 61.36                                    | 4.797                          | 44.8                             | .093         | .403             | 1.34               |
|               |   | API     | 14.00         | 13.06         | .4690         | 67.94            | 126.0                  | 527.8                             | 492.4                             | 134.0                      | 19.94                       | 456.8                                      | 65.26                                    | 4.787                          | 45.5                             | .099         | .444             | 1.48               |
|               | SCH 60  | XS API  | 14.00         | 13.00         | .5000         | 72.27            | 129.7                  | 527.8                             | 490.1                             | 132.7                      | 21.21                       | 483.8                                      | 69.11                                    | 4.776                          | 46.2                             | .105         | .486             | 1.62               |
|               |   | API     | 14.00         | 12.81         | .5940         | 85.26            | 141.1                  | 527.8                             | 483.0                             | 128.9                      | 25.02                       | 563.1                                      | 80.44                                    | 4.744                          | 47.8                             | .122         | .613             | 2.04               |
|               | SCH 80  | API     | 14.00         | 12.75         | .6250         | 89.50            | 144.8                  | 527.8                             | 480.7                             | 127.7                      | 26.26                       | 588.5                                      | 84.08                                    | 4.734                          | 48.2                             | .127         | .655             | 2.18               |
|               |   | API     | 14.00         | 12.50         | .7500         | 106.4            | 159.5                  | 527.8                             | 471.2                             | 122.7                      | 31.22                       | 687.3                                      | 98.19                                    | 4.692                          | 49.6                             | .146         | .826             | 2.75               |
|               | SCH 100                                       | API     | 14.00         | 12.12         | .9380         | 131.2            | 181.2                  | 527.8                             | 457.1                             | 115.4                      | 38.49                       | 825.1                                      | 117.9                                    | 4.630                          | 51.0                             | .167         | 1.09             | 3.63               |
|               | SCH 120                                       | API     | 14.00         | 11.81         | 1.094         | 151.2            | 198.6                  | 527.8                             | 445.3                             | 109.6                      | 44.36                       | 930.2                                      | 132.9                                    | 4.579                          | 51.7                             | .181         | 1.31             | 4.37               |
|               | SCH 140                                       | API     | 14.00         | 11.50         | 1.250         | 170.6            | 215.6                  | 527.8                             | 433.5                             | 103.9                      | 50.07                       | 1027                                       | 146.7                                    | 4.529                          | 52.2                             | .191         | 1.54             | 5.13               |
|               | SCH 160                                       | API     | 14.00         | 11.19         | 1.406         | 189.6            | 232.2                  | 527.8                             | 421.8                             | 98.31                      | 55.63                       | 1117                                       | 159.5                                    | 4.480                          | 52.4                             | .199         | 1.77             | 5.90               |

Thru NPS 10, wall thicknesses for SCH 40S and SCH 80S stainless steel pipes are the same as for SCH 40 and SCH 80 carbon steel pipes  
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# PIPE DATA

# TABLES P-1

| NPS<br>(inch) | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |     | DIMENSIONS    |               |               | WEIGHTS          |                        | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(in <sup>4</sup> ) | Section<br>Modulus<br>(in <sup>3</sup> ) | Radius of<br>Gyration<br>(in.) | Continuous Spans |              | Code Pressures   |                    |
|---------------|---|-----|---------------|---------------|---------------|------------------|------------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|--------------------------------|------------------|--------------|------------------|--------------------|
|               |   |     | O.D.<br>(in.) | I.D.<br>(in.) | Wall<br>(in.) | Empty<br>(lb/ft) | Waterfilled<br>(lb/ft) | External<br>(in <sup>2</sup> /ft) | Internal<br>(in <sup>2</sup> /ft) | Flow<br>(in <sup>2</sup> ) | Metal<br>(in <sup>2</sup> ) |  |  |                                | Span<br>(ft)     | Sag<br>(in.) | Design<br>(kPSI) | Bursting<br>(kPSI) |
| 16            | SCH 10  | API | 16.00         | 15.56         | .2190         | 37.00            | 119.4                  | 603.2                             | 586.7                             | 190.2                      | 10.86                       | 338.1                                      | 42.26                                    | 5.580                          | 37.6             | .034         | .101             | .335               |
|               |   | API | 16.00         | 15.50         | .2500         | 42.16            | 123.9                  | 603.2                             | 584.3                             | 188.7                      | 12.37                       | 383.7                                      | 47.96                                    | 5.569                          | 39.4             | .041         | .136             | .453               |
|               |   | API | 16.00         | 15.44         | .2810         | 47.29            | 128.3                  | 603.2                             | 582.0                             | 187.2                      | 13.88                       | 428.7                                      | 53.59                                    | 5.558                          | 40.9             | .048         | .171             | .571               |
|               | SCH 20  | API | 16.00         | 15.38         | .3120         | 52.40            | 132.8                  | 603.2                             | 579.7                             | 185.7                      | 15.38                       | 473.2                                      | 59.16                                    | 5.548                          | 42.2             | .055         | .207             | .689               |
|               |   | API | 16.00         | 15.31         | .3440         | 57.66            | 137.4                  | 603.2                             | 577.2                             | 184.1                      | 16.92                       | 518.6                                      | 64.83                                    | 5.537                          | 43.4             | .061         | .243             | .811               |
|               | SCH 30  | STD | 16.00         | 15.25         | .3750         | 62.73            | 141.8                  | 603.2                             | 574.9                             | 182.7                      | 18.41                       | 562.1                                      | 70.26                                    | 5.526                          | 44.5             | .068         | .279             | .930               |
|               |   | API | 16.00         | 15.12         | .4380         | 72.98            | 150.8                  | 603.2                             | 570.2                             | 179.6                      | 21.41                       | 648.7                                      | 81.09                                    | 5.504                          | 46.4             | .081         | .352             | 1.17               |
|               |   | API | 16.00         | 15.06         | .4690         | 77.99            | 155.1                  | 603.2                             | 567.8                             | 178.2                      | 22.88                       | 690.6                                      | 86.33                                    | 5.494                          | 47.2             | .087         | .388             | 1.29               |
|               | SCH 40  | XS  | 16.00         | 15.00         | .5000         | 82.98            | 159.5                  | 603.2                             | 565.5                             | 176.7                      | 24.35                       | 731.9                                      | 91.49                                    | 5.483                          | 47.9             | .093         | .424             | 1.41               |
|               |   | API | 16.00         | 14.75         | .6250         | 102.9            | 176.9                  | 603.2                             | 556.1                             | 170.9                      | 30.19                       | 893.5                                      | 111.7                                    | 5.440                          | 50.3             | .114         | .571             | 1.90               |
|               | SCH 60  | API | 16.00         | 14.69         | .6560         | 107.8            | 181.1                  | 603.2                             | 553.7                             | 169.4                      | 31.62                       | 932.3                                      | 116.5                                    | 5.430                          | 50.7             | .119         | .608             | 2.03               |
|               |   | API | 16.00         | 14.50         | .7500         | 122.5            | 194.0                  | 603.2                             | 546.6                             | 165.1                      | 35.93                       | 1047                                       | 130.9                                    | 5.398                          | 52.0             | .132         | .720             | 2.40               |
|               | SCH 80  | API | 16.00         | 14.31         | .8440         | 137.0            | 206.6                  | 603.2                             | 539.5                             | 160.9                      | 40.19                       | 1157                                       | 144.7                                    | 5.367                          | 52.9             | .144         | .833             | 2.78               |
|               | SCH 100                                       | API | 16.00         | 13.94         | 1.031         | 165.2            | 231.3                  | 603.2                             | 525.5                             | 152.6                      | 48.48                       | 1364                                       | 170.6                                    | 5.305                          | 54.3             | .163         | 1.06             | 3.54               |
|               | SCH 120                                       | API | 16.00         | 13.56         | 1.219         | 192.9            | 255.5                  | 603.2                             | 511.3                             | 144.5                      | 56.61                       | 1556                                       | 194.5                                    | 5.244                          | 55.2             | .178         | 1.30             | 4.32               |
|               | SCH 140                                       | API | 16.00         | 13.12         | 1.438         | 224.2            | 282.8                  | 603.2                             | 494.8                             | 135.3                      | 65.79                       | 1761                                       | 220.1                                    | 5.173                          | 55.8             | .192         | 1.57             | 5.25               |
|               | SCH 160                                       | API | 16.00         | 12.81         | 1.594         | 245.9            | 301.7                  | 603.2                             | 483.0                             | 128.9                      | 72.14                       | 1894                                       | 236.8                                    | 5.124                          | 56.0             | .199         | 1.78             | 5.92               |
| 18            | SCH 10  | API | 18.00         | 17.50         | .2500         | 47.51            | 151.7                  | 678.6                             | 659.7                             | 240.5                      | 13.94                       | 549.1                                      | 61.02                                    | 6.276                          | 40.1             | .035         | .121             | .402               |
|               |   | API | 18.00         | 17.44         | .2810         | 53.31            | 156.7                  | 678.6                             | 657.4                             | 238.8                      | 15.64                       | 614.0                                      | 68.23                                    | 6.265                          | 41.7             | .041         | .152             | .507               |
|               |   | API | 18.00         | 17.38         | .3120         | 59.09            | 161.8                  | 678.6                             | 655.1                             | 237.1                      | 17.34                       | 678.2                                      | 75.36                                    | 6.255                          | 43.2             | .047         | .183             | .612               |
|               | SCH 20  | API | 18.00         | 17.31         | .3440         | 65.03            | 167.0                  | 678.6                             | 652.6                             | 235.4                      | 19.08                       | 743.8                                      | 82.65                                    | 6.244                          | 44.5             | .053         | .216             | .720               |
|               |   | STD | 18.00         | 17.25         | .3750         | 70.76            | 172.0                  | 678.6                             | 650.3                             | 233.7                      | 20.76                       | 806.6                                      | 89.63                                    | 6.233                          | 45.7             | .059         | .248             | .826               |
|               |   | API | 18.00         | 17.19         | .4060         | 76.48            | 177.0                  | 678.6                             | 648.0                             | 232.0                      | 22.44                       | 868.8                                      | 96.53                                    | 6.222                          | 46.7             | .065         | .279             | .931               |
|               | SCH 30  | API | 18.00         | 17.12         | .4380         | 82.36            | 182.1                  | 678.6                             | 645.6                             | 230.3                      | 24.17                       | 932.2                                      | 103.6                                    | 6.211                          | 47.7             | .071         | .312             | 1.04               |
|               |   | API | 18.00         | 17.06         | .4690         | 88.03            | 187.0                  | 678.6                             | 643.2                             | 228.6                      | 25.83                       | 993.0                                      | 110.3                                    | 6.200                          | 48.6             | .077         | .344             | 1.15               |
|               |   | XS  | 18.00         | 17.00         | .5000         | 93.68            | 192.0                  | 678.6                             | 640.9                             | 227.0                      | 27.49                       | 1053                                       | 117.0                                    | 6.190                          | 49.4             | .082         | .376             | 1.25               |
|               | SCH 40  | API | 18.00         | 16.88         | .5620         | 104.9            | 201.8                  | 678.6                             | 636.2                             | 223.7                      | 30.79                       | 1171                                       | 130.2                                    | 6.168                          | 50.8             | .093         | .440             | 1.47               |
|               |   | API | 18.00         | 16.75         | .6250         | 116.3            | 211.7                  | 678.6                             | 631.5                             | 220.4                      | 34.12                       | 1289                                       | 143.2                                    | 6.147                          | 52.0             | .103         | .506             | 1.69               |
|               | SCH 60  | API | 18.00         | 16.50         | .7500         | 138.5            | 231.1                  | 678.6                             | 622.0                             | 213.8                      | 40.64                       | 1515                                       | 168.3                                    | 6.105                          | 54.0             | .120         | .638             | 2.13               |
|               | SCH 80  | API | 18.00         | 16.12         | .9380         | 171.3            | 259.8                  | 678.6                             | 607.9                             | 204.2                      | 50.28                       | 1835                                       | 203.9                                    | 6.041                          | 56.0             | .143         | .838             | 2.79               |
|               | SCH 100                                       | API | 18.00         | 15.69         | 1.156         | 208.5            | 292.2                  | 678.6                             | 591.4                             | 193.3                      | 61.17                       | 2180                                       | 242.2                                    | 5.969                          | 57.6             | .163         | 1.08             | 3.58               |
|               | SCH 120                                       | API | 18.00         | 15.25         | 1.375         | 244.7            | 323.8                  | 678.6                             | 574.9                             | 182.7                      | 71.81                       | 2498                                       | 277.6                                    | 5.898                          | 58.6             | .179         | 1.32             | 4.39               |
|               | SCH 140                                       | API | 18.00         | 14.88         | 1.562         | 274.9            | 350.2                  | 678.6                             | 560.8                             | 173.8                      | 80.66                       | 2749                                       | 305.5                                    | 5.838                          | 59.1             | .189         | 1.53             | 5.10               |
|               | SCH 160                                       | API | 18.00         | 14.44         | 1.781         | 309.3            | 380.2                  | 678.6                             | 544.3                             | 163.7                      | 90.75                       | 3020                                       | 335.6                                    | 5.769                          | 59.4             | .198         | 1.78             | 5.94               |
| 20            | SCH 10  | API | 20.00         | 19.50         | .2500         | 52.86            | 182.2                  | 754.0                             | 735.1                             | 298.6                      | 15.51                       | 756.4                                      | 75.64                                    | 6.983                          | 40.8             | .030         | .109             | .362               |
|               |   | API | 20.00         | 19.44         | .2810         | 59.33            | 187.8                  | 754.0                             | 732.8                             | 296.8                      | 17.41                       | 846.3                                      | 84.63                                    | 6.972                          | 42.5             | .035         | .137             | .456               |
|               |   | API | 20.00         | 19.38         | .3120         | 65.77            | 193.4                  | 754.0                             | 730.5                             | 294.9                      | 19.30                       | 935.3                                      | 93.53                                    | 6.962                          | 44.0             | .041         | .165             | .550               |
|               | SCH 20  | API | 20.00         | 19.31         | .3440         | 72.39            | 199.2                  | 754.0                             | 728.0                             | 292.9                      | 21.24                       | 1026                                       | 102.6                                    | 6.951                          | 45.4             | .046         | .194             | .648               |
|               |   | STD | 20.00         | 19.25         | .3750         | 78.79            | 204.8                  | 754.0                             | 725.7                             | 291.0                      | 23.12                       | 1113                                       | 111.3                                    | 6.940                          | 46.6             | .052         | .223             | .742               |
|               |   | API | 20.00         | 19.19         | .4060         | 85.17            | 210.4                  | 754.0                             | 723.4                             | 289.2                      | 24.99                       | 1200                                       | 120.0                                    | 6.929                          | 47.8             | .057         | .251             | .837               |
|               | SCH 30  | API | 20.00         | 19.12         | .4380         | 91.74            | 216.1                  | 754.0                             | 721.0                             | 287.2                      | 26.92                       | 1288                                       | 128.8                                    | 6.918                          | 48.8             | .063         | .281             | .936               |
|               |   | API | 20.00         | 19.06         | .4690         | 98.07            | 221.6                  | 754.0                             | 718.6                             | 285.4                      | 28.78                       | 1373                                       | 137.3                                    | 6.907                          | 49.8             | .068         | .309             | 1.03               |
|               |   | XS  | 20.00         | 19.00         | .5000         | 104.4            | 227.2                  | 754.0                             | 716.3                             | 283.5                      | 30.63                       | 1457                                       | 145.7                                    | 6.897                          | 50.6             | .073         | .338             | 1.13               |
|               | SCH 40  | API | 20.00         | 18.81         | .5940         | 123.4            | 243.8                  | 754.0                             | 709.2                             | 277.9                      | 36.21                       | 1706                                       | 170.6                                    | 6.864                          | 52.9             | .088         | .425             | 1.42               |
|               |   | API | 20.00         | 18.75         | .6250         | 129.6            | 249.2                  | 754.0                             | 706.9                             | 276.1                      | 38.04                       | 1787                                       | 178.7                                    | 6.854                          | 53.6             | .093         | .454             | 1.51               |
|               | SCH 60  | API | 20.00         | 18.38         | .8120         | 166.8            | 281.7                  | 754.0                             | 692.8                             | 265.2                      | 48.95                       | 2257                                       | 225.7                                    | 6.790                          | 56.6             | .118         | .631             | 2.10               |
|               | SCH 80  | API | 20.00         | 17.94         | 1.031         | 209.4            | 318.8                  | 754.0                             | 676.2                             | 252.7                      | 61.44                       | 2772                                       | 277.2                                    | 6.716                          | 59.0             | .142         | .841             | 2.80               |
|               | SCH 100                                       | API | 20.00         | 17.44         | 1.281         | 256.7            | 360.2                  | 754.0                             | 657.4                             | 238.8                      | 75.33                       | 3315                                       | 331.5                                    | 6.634                          | 60.7             | .163         | 1.09             | 3.62               |
|               | SCH 120                                       | API | 20.00         | 17.00         | 1.500         | 297.1            | 395.4                  | 754.0                             | 640.9                             | 227.0                      | 87.18                       | 3754                                       | 375.4                                    | 6.562                          | 61.6             | .177         | 1.30             | 4.35               |
|               | SCH 140                                       | API | 20.00         | 16.50         | 1.750         | 341.9            | 434.5                  | 754.0                             | 622.0                             | 213.8                      | 100.3                       | 4216                                       | 421.6                                    | 6.482                          | 62.3             | .190         | 1.56             | 5.20               |
|               | SCH 160                                       | API | 20.00         | 16.06         | 1.969         | 380.1            | 467.9                  | 754.0                             | 605.5                             | 202.6                      | 111.5                       | 4587                                       | 458.7                                    | 6.413                          | 62.6             | .198         | 1.79             | 5.96               |

# PIPE DATA

# TABLES P-1

| NPS<br>(inch) | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |         | DIMENSIONS    |               |               | WEIGHTS          |                        | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(in <sup>4</sup> ) | Section<br>Modulus<br>(in <sup>3</sup> ) | Radius of<br>Gyration<br>(in.) | Continuous Spans |              | Code Pressures   |                    |
|---------------|---|---------|---------------|---------------|---------------|------------------|------------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|--------------------------------|------------------|--------------|------------------|--------------------|
|               |   |         | O.D.<br>(in.) | I.D.<br>(in.) | Wall<br>(in.) | Empty<br>(lb/ft) | Waterfilled<br>(lb/ft) | External<br>(in <sup>2</sup> /ft) | Internal<br>(in <sup>2</sup> /ft) | Flow<br>(in <sup>2</sup> ) | Metal<br>(in <sup>2</sup> ) |  |  |                                | Span<br>(ft)     | Sag<br>(in.) | Design<br>(kPSI) | Bursting<br>(kPSI) |
| 22            | SCH 10  | API     | 22.00         | 21.50         | .2500         | 58.22            | 215.4                  | 829.4                             | 810.5                             | 363.1                      | 17.08                       | 1010                                       | 91.84                                    | 7.690                          | 41.3             | .026         | .099             | .329               |
|               |   | API     | 22.00         | 21.44         | .2810         | 65.34            | 221.6                  | 829.4                             | 808.2                             | 361.0                      | 19.17                       | 1131                                       | 102.8                                    | 7.679                          | 43.1             | .031         | .124             | .414               |
|               |   | API     | 22.00         | 21.38         | .3120         | 72.45            | 227.8                  | 829.4                             | 805.9                             | 358.9                      | 21.26                       | 1250                                       | 113.7                                    | 7.669                          | 44.7             | .036         | .150             | .500               |
|               |   | API     | 22.00         | 21.31         | .3440         | 79.76            | 234.2                  | 829.4                             | 803.4                             | 356.7                      | 23.40                       | 1372                                       | 124.8                                    | 7.658                          | 46.2             | .041         | .176             | .588               |
|               | SCH 20  | STD API | 22.00         | 21.25         | .3750         | 86.82            | 240.4                  | 829.4                             | 801.1                             | 354.7                      | 25.48                       | 1490                                       | 135.4                                    | 7.647                          | 47.5             | .046         | .202             | .674               |
|               |   | API     | 22.00         | 21.19         | .4060         | 93.87            | 246.5                  | 829.4                             | 798.8                             | 352.6                      | 27.54                       | 1606                                       | 146.0                                    | 7.636                          | 48.7             | .051         | .228             | .760               |
|               |   | API     | 22.00         | 21.12         | .4380         | 101.1            | 252.9                  | 829.4                             | 796.4                             | 350.5                      | 29.67                       | 1725                                       | 156.8                                    | 7.625                          | 49.8             | .056         | .255             | .850               |
|               |   | API     | 22.00         | 21.06         | .4690         | 108.1            | 259.0                  | 829.4                             | 794.0                             | 348.4                      | 31.72                       | 1839                                       | 167.2                                    | 7.614                          | 50.8             | .061         | .281             | .936               |
|               | SCH 30  | XS API  | 22.00         | 21.00         | .5000         | 115.1            | 265.1                  | 829.4                             | 791.7                             | 346.4                      | 33.77                       | 1952                                       | 177.5                                    | 7.603                          | 51.8             | .066         | .307             | 1.02               |
|               |   | API     | 22.00         | 20.50         | .7500         | 170.6            | 313.6                  | 829.4                             | 772.8                             | 330.1                      | 50.07                       | 2830                                       | 257.2                                    | 7.518                          | 57.3             | .101         | .519             | 1.73               |
|               | SCH 60  | API     | 22.00         | 20.25         | .8750         | 197.9            | 337.4                  | 829.4                             | 763.4                             | 322.1                      | 58.07                       | 3245                                       | 295.0                                    | 7.475                          | 59.1             | .116         | .627             | 2.09               |
|               | SCH 80  | API     | 22.00         | 19.75         | 1.125         | 251.4            | 384.1                  | 829.4                             | 744.6                             | 306.4                      | 73.78                       | 4030                                       | 366.4                                    | 7.391                          | 61.8             | .141         | .845             | 2.82               |
|               | SCH 100                                       | API     | 22.00         | 19.25         | 1.375         | 303.6            | 429.7                  | 829.4                             | 725.7                             | 291.0                      | 89.09                       | 4759                                       | 432.6                                    | 7.308                          | 63.5             | .161         | 1.07             | 3.56               |
|               | SCH 120                                       |         | 22.00         | 18.75         | 1.625         | 354.5            | 474.1                  | 829.4                             | 706.9                             | 276.1                      | 104.0                       | 5432                                       | 493.8                                    | 7.227                          | 64.6             | .176         | 1.29             | 4.31               |
|               | SCH 140                                       |         | 22.00         | 18.25         | 1.875         | 404.0            | 517.3                  | 829.4                             | 688.0                             | 261.6                      | 118.5                       | 6054                                       | 550.3                                    | 7.146                          | 65.2             | .188         | 1.52             | 5.08               |
|               | SCH 160                                       |         | 22.00         | 17.75         | 2.125         | 452.2            | 559.3                  | 829.4                             | 669.2                             | 247.4                      | 132.7                       | 6626                                       | 602.4                                    | 7.067                          | 65.6             | .197         | 1.76             | 5.87               |
| 24            | SCH 10  | API     | 24.00         | 23.50         | .2500         | 63.57            | 251.4                  | 904.8                             | 885.9                             | 433.7                      | 18.65                       | 1315                                       | 109.6                                    | 8.397                          | 41.8             | .023         | .090             | .301               |
|               |   | API     | 24.00         | 23.44         | .2810         | 71.36            | 258.2                  | 904.8                             | 883.6                             | 431.5                      | 20.94                       | 1473                                       | 122.7                                    | 8.387                          | 43.6             | .027         | .114             | .379               |
|               |   | API     | 24.00         | 23.38         | .3120         | 79.13            | 265.0                  | 904.8                             | 881.3                             | 429.2                      | 23.22                       | 1629                                       | 135.7                                    | 8.376                          | 45.3             | .032         | .137             | .458               |
|               |   | API     | 24.00         | 23.31         | .3440         | 87.13            | 272.0                  | 904.8                             | 878.8                             | 426.8                      | 25.57                       | 1789                                       | 149.1                                    | 8.365                          | 46.8             | .036         | .162             | .539               |
|               | SCH 20  | STD API | 24.00         | 23.25         | .3750         | 94.85            | 278.7                  | 904.8                             | 876.5                             | 424.6                      | 27.83                       | 1942                                       | 161.9                                    | 8.354                          | 48.2             | .041         | .185             | .618               |
|               |   | API     | 24.00         | 23.19         | .4060         | 102.6            | 285.4                  | 904.8                             | 874.2                             | 422.3                      | 30.09                       | 2095                                       | 174.6                                    | 8.343                          | 49.5             | .045         | .209             | .696               |
|               |   | API     | 24.00         | 23.12         | .4380         | 110.5            | 292.3                  | 904.8                             | 871.8                             | 420.0                      | 32.42                       | 2251                                       | 187.6                                    | 8.332                          | 50.7             | .050         | .233             | .778               |
|               |   | API     | 24.00         | 23.06         | .4690         | 118.2            | 299.0                  | 904.8                             | 869.4                             | 417.7                      | 34.67                       | 2401                                       | 200.1                                    | 8.321                          | 51.7             | .055         | .257             | .857               |
|               | SCH 30  | XS API  | 24.00         | 23.00         | .5000         | 125.8            | 305.7                  | 904.8                             | 867.1                             | 415.5                      | 36.91                       | 2549                                       | 212.4                                    | 8.310                          | 52.7             | .059         | .281             | .937               |
|               |   | API     | 24.00         | 22.88         | .5620         | 141.0            | 319.0                  | 904.8                             | 862.4                             | 411.0                      | 41.38                       | 2843                                       | 236.9                                    | 8.289                          | 54.5             | .068         | .329             | 1.10               |
|               | SCH 40  | API     | 24.00         | 22.75         | .6250         | 156.4            | 332.4                  | 904.8                             | 857.7                             | 406.5                      | 45.90                       | 3137                                       | 261.4                                    | 8.267                          | 56.1             | .077         | .377             | 1.26               |
|               |   | API     | 24.00         | 22.62         | .6880         | 171.7            | 345.8                  | 904.8                             | 852.9                             | 402.0                      | 50.39                       | 3426                                       | 285.5                                    | 8.246                          | 57.5             | .085         | .426             | 1.42               |
|               | SCH 60  | API     | 24.00         | 22.50         | .7500         | 186.7            | 358.9                  | 904.8                             | 848.2                             | 397.6                      | 54.78                       | 3705                                       | 308.8                                    | 8.224                          | 58.7             | .093         | .475             | 1.58               |
|               |   |         | 24.00         | 22.06         | .9690         | 238.9            | 404.5                  | 904.8                             | 831.7                             | 382.3                      | 70.11                       | 4657                                       | 388.1                                    | 8.150                          | 61.9             | .117         | .647             | 2.16               |
|               | SCH 80  |         | 24.00         | 21.56         | 1.219         | 297.3            | 455.4                  | 904.8                             | 812.9                             | 365.1                      | 87.24                       | 5676                                       | 473.0                                    | 8.066                          | 64.5             | .140         | .848             | 2.83               |
|               | SCH 100                                       |         | 24.00         | 20.94         | 1.531         | 368.3            | 517.4                  | 904.8                             | 789.3                             | 344.3                      | 108.1                       | 6852                                       | 571.0                                    | 7.962                          | 66.4             | .163         | 1.10             | 3.67               |
|               | SCH 120                                       |         | 24.00         | 20.38         | 1.812         | 430.5            | 571.7                  | 904.8                             | 768.2                             | 326.1                      | 126.3                       | 7825                                       | 652.0                                    | 7.871                          | 67.5             | .178         | 1.34             | 4.45               |
|               | SCH 140                                       |         | 24.00         | 19.88         | 2.062         | 484.3            | 618.7                  | 904.8                             | 749.3                             | 310.3                      | 142.1                       | 8625                                       | 718.8                                    | 7.790                          | 68.2             | .188         | 1.55             | 5.16               |
|               | SCH 160                                       |         | 24.00         | 19.31         | 2.344         | 543.5            | 670.3                  | 904.8                             | 728.0                             | 292.9                      | 159.5                       | 9458                                       | 788.2                                    | 7.701                          | 68.6             | .197         | 1.79             | 5.98               |
| 26            | SCH 10  | API     | 26.00         | 25.50         | .2500         | 68.92            | 290.1                  | 980.2                             | 961.3                             | 510.7                      | 20.22                       | 1676                                       | 129.0                                    | 9.104                          | 42.2             | .020         | .083             | .278               |
|               |   | API     | 26.00         | 25.44         | .2810         | 77.38            | 297.5                  | 980.2                             | 959.0                             | 508.2                      | 22.70                       | 1878                                       | 144.4                                    | 9.094                          | 44.1             | .024         | .105             | .350               |
|               |   | API     | 26.00         | 25.38         | .3120         | 85.81            | 304.8                  | 980.2                             | 956.7                             | 505.8                      | 25.18                       | 2077                                       | 159.8                                    | 9.083                          | 45.8             | .028         | .127             | .422               |
|               |   | API     | 26.00         | 25.31         | .3440         | 94.49            | 312.4                  | 980.2                             | 954.2                             | 503.2                      | 27.73                       | 2282                                       | 175.5                                    | 9.072                          | 47.4             | .032         | .149             | .497               |
|               | STD   | API     | 26.00         | 25.25         | .3750         | 102.9            | 319.7                  | 980.2                             | 951.9                             | 500.7                      | 30.19                       | 2478                                       | 190.6                                    | 9.061                          | 48.8             | .037         | .171             | .570               |
|               |   | API     | 26.00         | 25.19         | .4060         | 111.3            | 327.0                  | 980.2                             | 949.6                             | 498.3                      | 32.64                       | 2674                                       | 205.7                                    | 9.050                          | 50.2             | .041         | .193             | .642               |
|               |   | API     | 26.00         | 25.12         | .4380         | 119.9            | 334.5                  | 980.2                             | 947.2                             | 495.8                      | 35.17                       | 2874                                       | 221.1                                    | 9.039                          | 51.4             | .045         | .215             | .718               |
|               |   | API     | 26.00         | 25.06         | .4690         | 128.2            | 341.8                  | 980.2                             | 944.8                             | 493.3                      | 37.62                       | 3066                                       | 235.9                                    | 9.028                          | 52.5             | .049         | .237             | .791               |
|               | SCH 20  | XS API  | 26.00         | 25.00         | .5000         | 136.5            | 349.1                  | 980.2                             | 942.5                             | 490.9                      | 40.06                       | 3257                                       | 250.5                                    | 9.017                          | 53.6             | .054         | .259             | .864               |
|               |   | API     | 26.00         | 24.88         | .5620         | 153.1            | 363.5                  | 980.2                             | 937.8                             | 486.0                      | 44.91                       | 3635                                       | 279.6                                    | 8.996                          | 55.5             | .062         | .303             | 1.01               |
|               |   | API     | 26.00         | 24.75         | .6250         | 169.8            | 378.1                  | 980.2                             | 933.1                             | 481.1                      | 49.82                       | 4013                                       | 308.7                                    | 8.974                          | 57.1             | .070         | .348             | 1.16               |
|               |   | API     | 26.00         | 24.50         | .7500         | 202.8            | 406.9                  | 980.2                             | 923.6                             | 471.4                      | 59.49                       | 4746                                       | 365.0                                    | 8.931                          | 59.9             | .085         | .438             | 1.46               |
| 28            | SCH 10  | API     | 28.00         | 27.50         | .2500         | 74.28            | 331.5                  | 1056                              | 1037                              | 594.0                      | 21.79                       | 2098                                       | 149.9                                    | 9.812                          | 42.5             | .018         | .077             | .258               |
|               |   | API     | 28.00         | 27.44         | .2810         | 83.39            | 339.4                  | 1056                              | 1034                              | 591.3                      | 24.47                       | 2350                                       | 167.9                                    | 9.801                          | 44.5             | .022         | .097             | .325               |
|               |   | API     | 28.00         | 27.38         | .3120         | 92.49            | 347.4                  | 1056                              | 1032                              | 588.6                      | 27.14                       | 2601                                       | 185.8                                    | 9.790                          | 46.3             | .025         | .118             | .392               |
|               |   | API     | 28.00         | 27.31         | .3440         | 101.9            | 355.6                  | 1056                              | 1030                              | 585.9                      | 29.89                       | 2858                                       | 204.1                                    | 9.779                          | 47.9             | .029         | .138             | .461               |
|               |   | STD API | 28.00         | 27.25         | .3750         | 110.9            | 363.5                  | 1056                              | 1027                              | 583.2                      | 32.54                       | 3105                                       | 221.8                                    | 9.768                          | 49.4             | .033         | .159             | .529               |

# PIPE DATA

# TABLES P-1

| NPS<br>(inch)              | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |         | DIMENSIONS    |               |               | WEIGHTS          |                        | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(in <sup>4</sup> ) | Section<br>Modulus<br>(in <sup>3</sup> ) | Radius of<br>Gyration<br>(in.) | Continuous Spans |              | Code Pressures   |                    |      |      |
|----------------------------|---|---------|---------------|---------------|---------------|------------------|------------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|--------------------------------|------------------|--------------|------------------|--------------------|------|------|
|                            |   |         | O.D.<br>(in.) | I.D.<br>(in.) | Wall<br>(in.) | Empty<br>(lb/ft) | Waterfilled<br>(lb/ft) | External<br>(in <sup>2</sup> /ft) | Internal<br>(in <sup>2</sup> /ft) | Flow<br>(in <sup>2</sup> ) | Metal<br>(in <sup>2</sup> ) |  |  |                                | Span<br>(ft)     | Sag<br>(in.) | Design<br>(kPSI) | Bursting<br>(kPSI) |      |      |
|                            | SCH 20<br>SCH 30                              | XS API  | 28.00         | 27.19         | .4060         | 119.9            | 371.3                  | 1056                              | 1025                              | 580.6                      | 35.20                       | 3351                                       | 239.3                                    | 9.757                          | 50.8             | .037         | .179             | .596               |      |      |
|                            |   | API     | 28.00         | 27.12         | .4380         | 129.3            | 379.5                  | 1056                              | 1023                              | 577.8                      | 37.93                       | 3602                                       | 257.3                                    | 9.746                          | 52.1             | .041         | .200             | .666               |      |      |
|                            |   | API     | 28.00         | 27.06         | .4690         | 138.2            | 387.3                  | 1056                              | 1020                              | 575.2                      | 40.56                       | 3844                                       | 274.6                                    | 9.735                          | 53.3             | .045         | .220             | .734               |      |      |
|                            |   | API     | 28.00         | 27.00         | .5000         | 147.2            | 395.1                  | 1056                              | 1018                              | 572.6                      | 43.20                       | 4085                                       | 291.8                                    | 9.724                          | 54.3             | .049         | .240             | .801               |      |      |
|                            |   | API     | 28.00         | 26.75         | .6250         | 183.2            | 426.5                  | 1056                              | 1008                              | 562.0                      | 53.75                       | 5038                                       | 359.8                                    | 9.681                          | 58.1             | .064         | .323             | 1.08               |      |      |
|                            |   | API     | 28.00         | 26.50         | .7500         | 218.8            | 457.6                  | 1056                              | 999.0                             | 551.5                      | 64.21                       | 5964                                       | 426.0                                    | 9.638                          | 61.0             | .079         | .406             | 1.35               |      |      |
| 30                         | SCH 10  | API     | 30.00         | 29.44         | .2810         | 89.41            | 384.1                  | 1131                              | 1110                              | 680.6                      | 26.24                       | 2897                                       | 193.1                                    | 10.51                          | 44.8             | .019         | .091             | .303               |      |      |
|                            |   | API     | 30.00         | 29.38         | .3120         | 99.17            | 392.7                  | 1131                              | 1107                              | 677.8                      | 29.10                       | 3206                                       | 213.8                                    | 10.50                          | 46.7             | .023         | .110             | .366               |      |      |
|                            |   | API     | 30.00         | 29.31         | .3440         | 109.2            | 401.4                  | 1131                              | 1105                              | 674.8                      | 32.05                       | 3524                                       | 234.9                                    | 10.49                          | 48.4             | .026         | .129             | .430               |      |      |
|                            |   | STD API | 30.00         | 29.25         | .3750         | 118.9            | 409.9                  | 1131                              | 1103                              | 672.0                      | 34.90                       | 3829                                       | 255.3                                    | 10.47                          | 49.9             | .030         | .148             | .493               |      |      |
|                            |   | API     | 30.00         | 29.19         | .4060         | 128.6            | 418.4                  | 1131                              | 1100                              | 669.1                      | 37.75                       | 4133                                       | 275.5                                    | 10.46                          | 51.3             | .034         | .167             | .556               |      |      |
|                            | SCH 20<br>SCH 30                              | XS API  | 30.00         | 29.12         | .4380         | 138.6            | 427.1                  | 1131                              | 1098                              | 666.2                      | 40.68                       | 4445                                       | 296.3                                    | 10.45                          | 52.7             | .037         | .186             | .621               |      |      |
|                            |   | API     | 30.00         | 29.06         | .4690         | 148.3            | 435.5                  | 1131                              | 1096                              | 663.3                      | 43.51                       | 4744                                       | 316.3                                    | 10.44                          | 53.9             | .041         | .205             | .684               |      |      |
|                            |   | API     | 30.00         | 29.00         | .5000         | 157.9            | 443.9                  | 1131                              | 1093                              | 660.5                      | 46.34                       | 5042                                       | 336.1                                    | 10.43                          | 55.0             | .045         | .224             | .747               |      |      |
|                            |   | API     | 30.00         | 28.75         | .6250         | 196.6            | 477.7                  | 1131                              | 1084                              | 649.2                      | 57.68                       | 6224                                       | 414.9                                    | 10.39                          | 58.9             | .059         | .301             | 1.00               |      |      |
|                            |   | API     | 30.00         | 28.50         | .7500         | 234.9            | 511.1                  | 1131                              | 1074                              | 637.9                      | 68.92                       | 7375                                       | 491.7                                    | 10.34                          | 62.0             | .073         | .378             | 1.26               |      |      |
| 32                         | SCH 10  | API     | 32.00         | 31.50         | .2500         | 84.98            | 422.4                  | 1206                              | 1188                              | 779.3                      | 24.94                       | 3142                                       | 196.4                                    | 11.23                          | 43.1             | .015         | .068             | .226               |      |      |
|                            |   | API     | 32.00         | 31.44         | .2810         | 95.43            | 431.6                  | 1206                              | 1185                              | 776.2                      | 28.00                       | 3522                                       | 220.1                                    | 11.21                          | 45.2             | .018         | .085             | .284               |      |      |
|                            |   | API     | 32.00         | 31.38         | .3120         | 105.9            | 440.7                  | 1206                              | 1183                              | 773.2                      | 31.06                       | 3899                                       | 243.7                                    | 11.20                          | 47.0             | .021         | .103             | .343               |      |      |
|                            |   | API     | 32.00         | 31.31         | .3440         | 116.6            | 450.0                  | 1206                              | 1180                              | 770.0                      | 34.21                       | 4286                                       | 267.9                                    | 11.19                          | 48.8             | .024         | .121             | .403               |      |      |
|                            |   | STD API | 32.00         | 31.25         | .3750         | 127.0            | 459.1                  | 1206                              | 1178                              | 767.0                      | 37.26                       | 4658                                       | 291.2                                    | 11.18                          | 50.4             | .027         | .139             | .462               |      |      |
|                            |   | API     | 32.00         | 31.19         | .4060         | 137.3            | 468.1                  | 1206                              | 1176                              | 764.0                      | 40.30                       | 5029                                       | 314.3                                    | 11.17                          | 51.8             | .031         | .156             | .521               |      |      |
|                            |   | API     | 32.00         | 31.12         | .4380         | 148.0            | 477.5                  | 1206                              | 1173                              | 760.8                      | 43.43                       | 5409                                       | 338.1                                    | 11.16                          | 53.2             | .034         | .175             | .582               |      |      |
|                            |   | API     | 32.00         | 31.06         | .4690         | 158.3            | 486.5                  | 1206                              | 1171                              | 757.8                      | 46.46                       | 5775                                       | 360.9                                    | 11.15                          | 54.5             | .037         | .192             | .641               |      |      |
|                            | SCH 20<br>SCH 30<br>SCH 40                    | XS API  | 32.00         | 31.00         | .5000         | 168.6            | 495.5                  | 1206                              | 1169                              | 754.8                      | 49.48                       | 6139                                       | 383.7                                    | 11.14                          | 55.7             | .041         | .210             | .700               |      |      |
|                            |   | API     | 32.00         | 30.75         | .6250         | 209.9            | 531.5                  | 1206                              | 1159                              | 742.6                      | 61.60                       | 7583                                       | 474.0                                    | 11.09                          | 59.7             | .055         | .282             | .940               |      |      |
|                            |   | API     | 32.00         | 30.62         | .6880         | 230.6            | 549.6                  | 1206                              | 1154                              | 736.6                      | 67.68                       | 8298                                       | 518.6                                    | 11.07                          | 61.4             | .061         | .318             | 1.06               |      |      |
|                            |   | API     | 32.00         | 30.50         | .7500         | 250.9            | 567.3                  | 1206                              | 1150                              | 730.6                      | 73.63                       | 8993                                       | 562.1                                    | 11.05                          | 63.0             | .068         | .354             | 1.18               |      |      |
| 34                         | SCH 10  | API     | 34.00         | 33.50         | .2500         | 90.34            | 472.0                  | 1282                              | 1263                              | 881.4                      | 26.51                       | 3774                                       | 222.0                                    | 11.93                          | 43.4             | .013         | .064             | .212               |      |      |
|                            |   | API     | 34.00         | 33.44         | .2810         | 101.4            | 481.7                  | 1282                              | 1261                              | 878.2                      | 29.77                       | 4231                                       | 248.9                                    | 11.92                          | 45.5             | .016         | .080             | .267               |      |      |
|                            |   | API     | 34.00         | 33.38         | .3120         | 112.5            | 491.4                  | 1282                              | 1258                              | 874.9                      | 33.02                       | 4685                                       | 275.6                                    | 11.91                          | 47.4             | .019         | .097             | .323               |      |      |
|                            |   | API     | 34.00         | 33.31         | .3440         | 124.0            | 501.4                  | 1282                              | 1256                              | 871.5                      | 36.37                       | 5151                                       | 303.0                                    | 11.90                          | 49.2             | .022         | .114             | .380               |      |      |
|                            |   | STD API | 34.00         | 33.25         | .3750         | 135.0            | 511.0                  | 1282                              | 1253                              | 868.3                      | 39.61                       | 5599                                       | 329.4                                    | 11.89                          | 50.8             | .025         | .130             | .435               |      |      |
|                            |   | API     | 34.00         | 33.19         | .4060         | 146.0            | 520.6                  | 1282                              | 1251                              | 865.1                      | 42.85                       | 6046                                       | 355.6                                    | 11.88                          | 52.3             | .028         | .147             | .490               |      |      |
|                            |   | API     | 34.00         | 33.12         | .4380         | 157.4            | 530.5                  | 1282                              | 1249                              | 861.7                      | 46.18                       | 6504                                       | 382.6                                    | 11.87                          | 53.7             | .031         | .164             | .547               |      |      |
|                            |   | API     | 34.00         | 33.06         | .4690         | 168.4            | 540.1                  | 1282                              | 1246                              | 858.5                      | 49.40                       | 6945                                       | 408.5                                    | 11.86                          | 55.0             | .034         | .181             | .603               |      |      |
|                            | SCH 20<br>SCH 30<br>SCH 40                    | XS API  | 34.00         | 33.00         | .5000         | 179.3            | 549.7                  | 1282                              | 1244                              | 855.3                      | 52.62                       | 7383                                       | 434.3                                    | 11.85                          | 56.2             | .038         | .198             | .659               |      |      |
|                            |   | API     | 34.00         | 32.75         | .6250         | 223.3            | 588.1                  | 1282                              | 1235                              | 842.4                      | 65.53                       | 9128                                       | 536.9                                    | 11.80                          | 60.4             | .051         | .265             | .884               |      |      |
|                            |   | API     | 34.00         | 32.62         | .6880         | 245.4            | 607.4                  | 1282                              | 1230                              | 835.9                      | 72.00                       | 9992                                       | 587.7                                    | 11.78                          | 62.2             | .057         | .299             | .998               |      |      |
|                            |   | API     | 34.00         | 32.50         | .7500         | 267.0            | 626.2                  | 1282                              | 1225                              | 829.6                      | 78.34                       | 10832                                      | 637.2                                    | 11.76                          | 63.8             | .063         | .333             | 1.11               |      |      |
|                            |   | 36      | SCH 10        | API           | 36.00         | 35.50            | .2500                  | 95.69                             | 524.3                             | 1357                       | 1338                        | 989.8                                      | 28.08                                    | 4486                           | 249.2            | 12.64        | 43.6             | .012               | .060 | .201 |
|                            |   |         |               | API           | 36.00         | 35.44            | .2810                  | 107.5                             | 534.6                             | 1357                       | 1336                        | 986.3                                      | 31.53                                    | 5029                           | 279.4            | 12.63        | 45.7             | .014               | .076 | .253 |
| API                        | 36.00   |         |               | 35.38         | .3120         | 119.2            | 544.8                  | 1357                              | 1334                              | 982.9                      | 34.98                       | 5569                                       | 309.4                                    | 12.62                          | 47.7             | .017         | .091             | .305               |      |      |
| API                        | 36.00   |         |               | 35.31         | .3440         | 131.3            | 555.4                  | 1357                              | 1331                              | 979.3                      | 38.53                       | 6124                                       | 340.2                                    | 12.61                          | 49.5             | .020         | .108             | .358               |      |      |
| STD API                    | 36.00   |         |               | 35.25         | .3750         | 143.0            | 565.6                  | 1357                              | 1329                              | 975.9                      | 41.97                       | 6659                                       | 369.9                                    | 12.60                          | 51.1             | .023         | .123             | .411               |      |      |
| API                        | 36.00   |         |               | 35.19         | .4060         | 154.7            | 575.8                  | 1357                              | 1327                              | 972.5                      | 45.40                       | 7191                                       | 399.5                                    | 12.59                          | 52.7             | .026         | .139             | .463               |      |      |
| SCH 20<br>SCH 30<br>SCH 40 | XS API  | API     | 36.00         | 35.12         | .4380         | 166.8            | 586.3                  | 1357                              | 1324                              | 968.9                      | 48.93                       | 7737                                       | 429.8                                    | 12.57                          | 54.1             | .029         | .155             | .517               |      |      |
|                            |   | API     | 36.00         | 35.06         | .4690         | 178.4            | 596.5                  | 1357                              | 1322                              | 965.5                      | 52.35                       | 8263                                       | 459.0                                    | 12.56                          | 55.5             | .032         | .171             | .569               |      |      |
|                            |   | API     | 36.00         | 35.00         | .5000         | 190.0            | 606.7                  | 1357                              | 1319                              | 962.1                      | 55.76                       | 8786                                       | 488.1                                    | 12.55                          | 56.7             | .035         | .187             | .622               |      |      |
|                            |   | API     | 36.00         | 34.88         | .5620         | 213.2            | 626.9                  | 1357                              | 1315                              | 955.3                      | 62.57                       | 9825                                       | 545.8                                    | 12.53                          | 59.0             | .041         | .218             | .727               |      |      |
|                            | API   | API     | 36.00         | 34.75         | .6250         | 236.7            | 647.4                  | 1357                              | 1310                              | 948.4                      | 69.46                       | 10868                                      | 603.8                                    | 12.51                          | 61.1             | .047         | .250             | .834               |      |      |
|                            |   | API     | 36.00         | 34.50         | .7500         | 283.1            | 687.9                  | 1357                              | 1301                              | 934.8                      | 83.06                       | 12906                                      | 717.0                                    | 12.47                          | 64.6             | .059         | .314             | 1.05               |      |      |

# PERSONNEL CLEARANCES

# CHART P-2

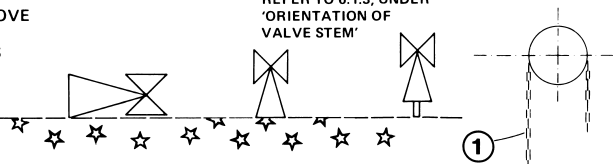
## CLEARANCES TO MANUAL VALVES AND SUGGESTED OPERATING HEIGHTS

### OVERHEAD VALVES

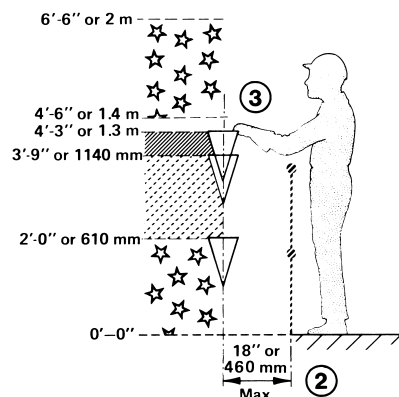
FOR VALVE OPERATION ABOVE  
6'-6" or 2 m, REFER TO 6.1.3,  
UNDER 'OPERATING ACCESS  
TO VALVES

6'-6" or 2 m  
MINIMUM ABOVE  
FLOOR or PLATFORM

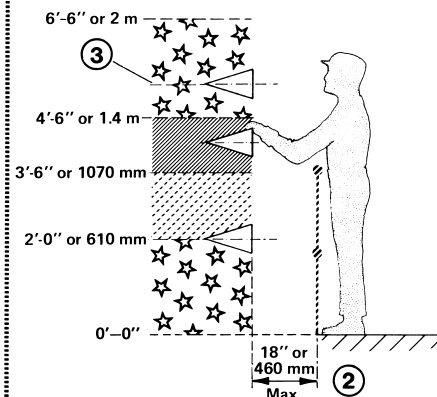
INVERTED VALVES:  
REFER TO 6.1.3, UNDER  
'ORIENTATION OF  
VALVE STEM'



### VERTICAL VALVES



### HORIZONTAL VALVES



### ZONES

- PREFERRED ELEVATIONS
- SECOND-CHOICE ELEVATIONS
- LEG OR HEAD HAZARD, UNLESS PROTECTION GIVEN BY RAILING, PIPING, EQUIPMENT, Etc.

### NOTES

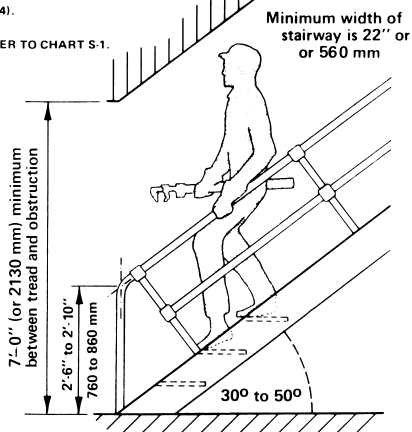
- (1) TAKE CHAINS TO 3'-0" (OR 900 mm) FROM OPERATING FLOOR LEVEL. DO NOT HANG CHAINS IN A WALKWAY.
- (2) DIMENSION APPLIES IF A RAILING IS PRESENT.
- (3) IF A RAILING IS PRESENT, COMFORTABLE OPERATING ELEVATION IS 5'-0" TO 5'-6" (OR 1.5 TO 1.7 m).
- (4) GENERAL CLEARANCE FORMULAS ARE:  
(a) 5.5 - (pitch angle/30) ft (b) 1.68 - (pitch angle/100) m.

TABLE 6.1 GIVES ADDITIONAL DIMENSIONS

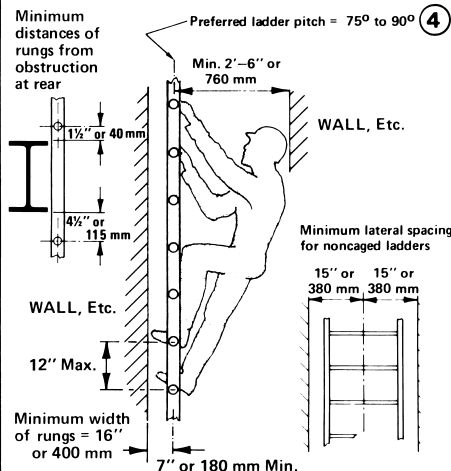
## CLEARANCES AROUND STAIRWAYS & LADDERS

DATA FROM THE CODE OF FEDERAL  
REGULATIONS 1910--"OCCUPATIONAL  
SAFETY AND HEALTH STANDARDS"  
(1984).

REFER TO CHART S-1.



Minimum  
distances of  
rungs from  
obstruction  
at rear

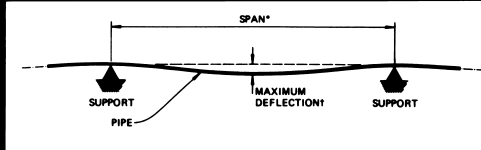


### COEFFICIENTS OF EXPANSION OF DIFFERENT PIPING MATERIALS (in inches/degree/inch of length)

| MATERIALS       | FAHRENHEIT  | CELSIUS      | MATERIALS                            | FAHRENHEIT | CELSIUS     |
|-----------------|-------------|--------------|--------------------------------------|------------|-------------|
| Aluminum        | 0.000 012 8 | 0.000 023 1  | ABS: Acrylonitrile-butadiene-styrene | 0.000 035  | 0.000 063   |
| Carbon steel    | 0.000 006 5 | 0.000 011 7  | HDPE: High-density polyethylene      | 0.000 067  | 0.000 12    |
| Cast iron       | 0.000 005 9 | 0.000 010 62 | PE: Polyethylene                     | 0.000 083  | 0.000 15    |
| Copper          | 0.000 009 3 | 0.000 016 8  | CPVC: Chlorinated polyvinyl chloride | 0.000 044  | 0.000 079 2 |
| Stainless steel | 0.000 009 9 | 0.000 017 82 | PVC: Polyvinyl chloride              | 0.000 028  | 0.000 050 4 |

# SPANS OF HORIZONTAL PIPE

THESE TABLES GIVE SPANS SUITABLE FOR PIPE ARRANGED IN PIPEWAYS, AND APPLY WHEN THE SPAN IS PART OF A STRAIGHT PIPE, WITH TWO OR MORE SPANS AT EACH END.



## TABLE S-1

FOR VALUES OF BENDING STRESS & MODULUS, REFER TO CHARTS S-2

STEEL PIPE, SCHEDULE 160

| NOMINAL PIPE SIZE | PIPE SPAN* |       | WEIGHT OF WATER-FILLED PIPE SPAN (Lb) | MAXIMUM DEFLECTION* (In.) |
|-------------------|------------|-------|---------------------------------------|---------------------------|
|                   | Ft.        | In.   |                                       |                           |
| 1.0-INCH          | 15         | 8.77  | 48                                    | 0.234                     |
| 1.5-INCH          | 19         | 3.28  | 105                                   | 0.243                     |
| 2.0-INCH          | 21         | 6.79  | 182                                   | 0.243                     |
| 2.5-INCH          | 23         | 9.87  | 275                                   | 0.245                     |
| 3.0-INCH          | 26         | 3.66  | 438                                   | 0.245                     |
| 4.0-INCH          | 29         | 9.30  | 793                                   | 0.245                     |
| 6.0-INCH          | 36         | 2.01  | 1,970                                 | 0.245                     |
| 8.0-INCH          | 41         | 2.89  | 3,732                                 | 0.245                     |
| 10.0-INCH         | 45         | 11.75 | 6,465                                 | 0.244                     |
| 12.0-INCH         | 50         | 0.40  | 9,801                                 | 0.244                     |
| 14.0-INCH         | 52         | 4.67  | 12,186                                | 0.243                     |
| 16.0-INCH         | 56         | 0.99  | 16,875                                | 0.244                     |
| 18.0-INCH         | 59         | 5.13  | 22,582                                | 0.244                     |
| 20.0-INCH         | 62         | 8.17  | 29,266                                | 0.244                     |
| 24.0-INCH         | 68         | 7.74  | 45,923                                | 0.244                     |

STEEL PIPE, SCHEDULE 20

| NOMINAL PIPE SIZE | PIPE SPAN* |       | WEIGHT OF WATER-FILLED PIPE SPAN (Lb) | MAXIMUM DEFLECTION* (In.) |
|-------------------|------------|-------|---------------------------------------|---------------------------|
|                   | Ft.        | In.   |                                       |                           |
| 8.0-INCH          | 34         | 6.46  | 1,551                                 | 0.172                     |
| 10.0-INCH         | 36         | 4.22  | 2,324                                 | 0.152                     |
| 12.0-INCH         | 37         | 9.18  | 3,199                                 | 0.139                     |
| 14.0-INCH         | 41         | 0.64  | 4,385                                 | 0.149                     |
| 16.0-INCH         | 42         | 4.07  | 5,593                                 | 0.139                     |
| 18.0-INCH         | 43         | 2.92  | 6,384                                 | 0.129                     |
| 20.0-INCH         | 46         | 7.22  | 9,553                                 | 0.135                     |
| 24.0-INCH         | 48         | 2.35  | 13,437                                | 0.120                     |
| 30.0-INCH         | 54         | 11.58 | 24,415                                | 0.125                     |

STEEL PIPE, SCHEDULE 10

| NOMINAL PIPE SIZE | PIPE SPAN* |       | WEIGHT OF WATER-FILLED PIPE SPAN (Lb) | MAXIMUM DEFLECTION* (In.) |
|-------------------|------------|-------|---------------------------------------|---------------------------|
|                   | Ft.        | In.   |                                       |                           |
| 1.0-INCH          | 15         | 11.14 | 29                                    | 0.240                     |
| 1.5-INCH          | 18         | 5.62  | 56                                    | 0.223                     |
| 2.0-INCH          | 19         | 11.77 | 84                                    | 0.209                     |
| 2.5-INCH          | 21         | 7.24  | 127                                   | 0.202                     |
| 3.0-INCH          | 22         | 10.63 | 182                                   | 0.186                     |
| 4.0-INCH          | 24         | 5.31  | 288                                   | 0.164                     |
| 6.0-INCH          | 27         | 5.75  | 632                                   | 0.141                     |
| 8.0-INCH          | 29         | 9.72  | 1,103                                 | 0.128                     |
| 10.0-INCH         | 32         | 0.93  | 1,782                                 | 0.119                     |
| 12.0-INCH         | 33         | 11.37 | 2,592                                 | 0.112                     |
| 14.0-INCH         | 38         | 5.23  | 3,809                                 | 0.131                     |
| 16.0-INCH         | 39         | 4.50  | 4,886                                 | 0.120                     |
| 18.0-INCH         | 40         | 1.82  | 6,087                                 | 0.111                     |
| 20.0-INCH         | 40         | 8.77  | 7,454                                 | 0.103                     |
| 24.0-INCH         | 41         | 9.43  | 10,530                                | 0.090                     |

STEEL PIPE, SCHEDULE 80

| NOMINAL PIPE SIZE | PIPE SPAN* |       | WEIGHT OF WATER-FILLED PIPE SPAN (Lb) | MAXIMUM DEFLECTION* (In.) |
|-------------------|------------|-------|---------------------------------------|---------------------------|
|                   | Ft.        | In.   |                                       |                           |
| 1.0-INCH          | 16         | 1.05  | 40                                    | 0.244                     |
| 1.5-INCH          | 19         | 4.29  | 85                                    | 0.245                     |
| 2.0-INCH          | 21         | 6.49  | 136                                   | 0.243                     |
| 2.5-INCH          | 23         | 9.02  | 225                                   | 0.244                     |
| 3.0-INCH          | 26         | 0.66  | 342                                   | 0.241                     |
| 4.0-INCH          | 29         | 3.07  | 584                                   | 0.236                     |
| 6.0-INCH          | 35         | 0.22  | 1,396                                 | 0.230                     |
| 8.0-INCH          | 39         | 4.67  | 2,489                                 | 0.223                     |
| 10.0-INCH         | 43         | 8.21  | 4,172                                 | 0.220                     |
| 12.0-INCH         | 47         | 5.26  | 6,290                                 | 0.219                     |
| 14.0-INCH         | 49         | 9.95  | 7,883                                 | 0.220                     |
| 16.0-INCH         | 52         | 10.78 | 10,334                                | 0.217                     |
| 18.0-INCH         | 56         | 0.58  | 14,545                                | 0.217                     |
| 20.0-INCH         | 59         | 0.02  | 18,736                                | 0.216                     |
| 24.0-INCH         | 64         | 5.48  | 29,341                                | 0.215                     |

ALUMINUM PIPE, SCHEDULE 80

| NOMINAL PIPE SIZE | PIPE SPAN* |       | WEIGHT OF WATER-FILLED PIPE SPAN (Lb) | MAXIMUM DEFLECTION* (In.) |
|-------------------|------------|-------|---------------------------------------|---------------------------|
|                   | Ft.        | In.   |                                       |                           |
| 1.0-INCH          | 17         | 4.67  | 18                                    | 0.414                     |
| 1.5-INCH          | 20         | 2.26  | 41                                    | 0.386                     |
| 2.0-INCH          | 22         | 0.19  | 66                                    | 0.367                     |
| 2.5-INCH          | 24         | 5.26  | 110                                   | 0.374                     |
| 3.0-INCH          | 26         | 4.25  | 169                                   | 0.357                     |
| 4.0-INCH          | 28         | 11.94 | 295                                   | 0.336                     |
| 6.0-INCH          | 33         | 11.69 | 719                                   | 0.314                     |
| 8.0-INCH          | 37         | 6.31  | 1,306                                 | 0.294                     |
| 10.0-INCH         | 39         | 8.42  | 1,936                                 | 0.264                     |

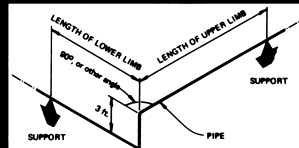
STEEL PIPE, SCHEDULE 40

| NOMINAL PIPE SIZE | PIPE SPAN* |       | WEIGHT OF WATER-FILLED PIPE SPAN (Lb) | MAXIMUM DEFLECTION* (In.) |
|-------------------|------------|-------|---------------------------------------|---------------------------|
|                   | Ft.        | In.   |                                       |                           |
| 1.0-INCH          | 16         | 1.07  | 33                                    | 0.244                     |
| 1.5-INCH          | 19         | 0.49  | 69                                    | 0.237                     |
| 2.0-INCH          | 20         | 11.53 | 107                                   | 0.230                     |
| 2.5-INCH          | 23         | 3.20  | 183                                   | 0.234                     |
| 3.0-INCH          | 25         | 3.65  | 273                                   | 0.227                     |
| 4.0-INCH          | 28         | 1.01  | 458                                   | 0.218                     |
| 6.0-INCH          | 32         | 10.37 | 1,035                                 | 0.202                     |
| 8.0-INCH          | 36         | 7.40  | 1,836                                 | 0.193                     |
| 10.0-INCH         | 40         | 0.55  | 2,987                                 | 0.185                     |
| 12.0-INCH         | 42         | 11.48 | 4,386                                 | 0.180                     |
| 14.0-INCH         | 44         | 11.52 | 5,463                                 | 0.179                     |
| 16.0-INCH         | 47         | 10.83 | 7,640                                 | 0.178                     |
| 18.0-INCH         | 50         | 10.65 | 10,289                                | 0.179                     |
| 20.0-INCH         | 52         | 11.02 | 12,880                                | 0.174                     |
| 24.0-INCH         | 57         | 5.84  | 19,844                                | 0.171                     |

ALUMINUM PIPE, SCHEDULE 40

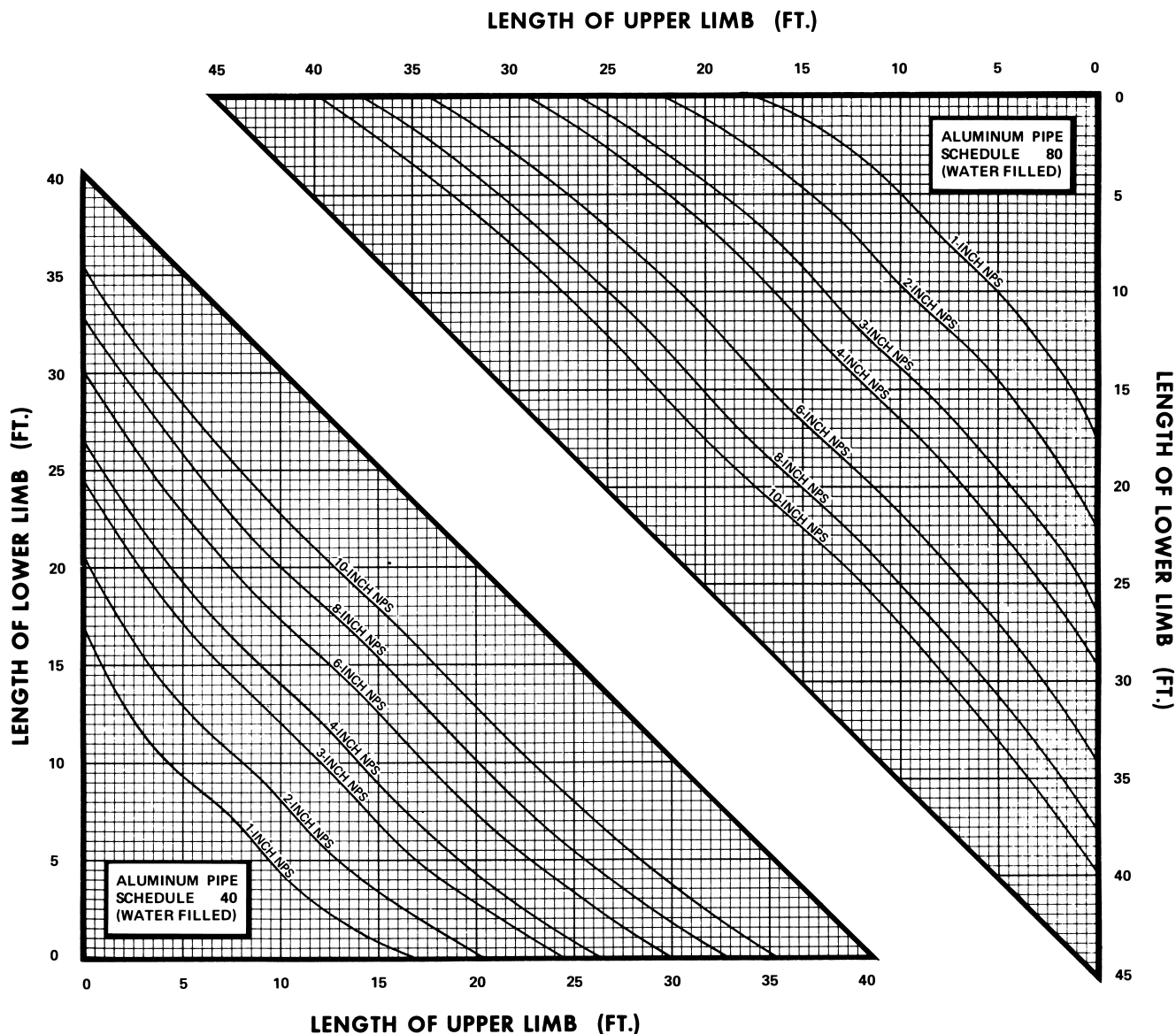
| NOMINAL PIPE SIZE | PIPE SPAN* |       | WEIGHT OF WATER-FILLED PIPE SPAN (Lb) | MAXIMUM DEFLECTION* (In.) |
|-------------------|------------|-------|---------------------------------------|---------------------------|
|                   | Ft.        | In.   |                                       |                           |
| 1.0-INCH          | 16         | 8.12  | 16                                    | 0.381                     |
| 1.5-INCH          | 18         | 11.07 | 34                                    | 0.339                     |
| 2.0-INCH          | 20         | 3.81  | 55                                    | 0.313                     |
| 2.5-INCH          | 22         | 10.19 | 93                                    | 0.327                     |
| 3.0-INCH          | 24         | 4.06  | 142                                   | 0.305                     |
| 4.0-INCH          | 26         | 4.46  | 244                                   | 0.278                     |
| 6.0-INCH          | 29         | 10.16 | 569                                   | 0.242                     |
| 8.0-INCH          | 32         | 8.17  | 1,029                                 | 0.223                     |
| 10.0-INCH         | 35         | 3.12  | 1,696                                 | 0.208                     |

# SPANS OF HORIZONTAL PIPE WITH 3-FT. RISE OR FALL



## CHARTS S-2

THESE CHARTS GIVE THE MAXIMUM LENGTH PERMISSIBLE FOR EITHER HORIZONTAL LIMB IN THE PIPING ARRANGEMENT SHOWN, AND APPLY WHEN THE SPAN INCLUDING THE RISE OR FALL IS CONTINUOUS WITH TWO OR MORE STRAIGHT SPANS AT EACH END.

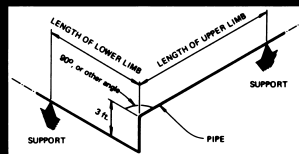


### LOWER CHART: SCH 40, ALUMINUM

Data for water-filled steel pipe are based on a maximum bending stress of 4000 PSI, occurring at supports and due to bending by the weight of pipe plus water: applied stresses may increase the resultant tensile stress. These data apply to carbon-steel and stainless-steel pipe having a tensile modulus of elasticity of 29,000,000 PSI. For water-filled aluminum pipe, spans are similarly based on a stress of 2000 PSI and a modulus of 10,000,000 PSI.

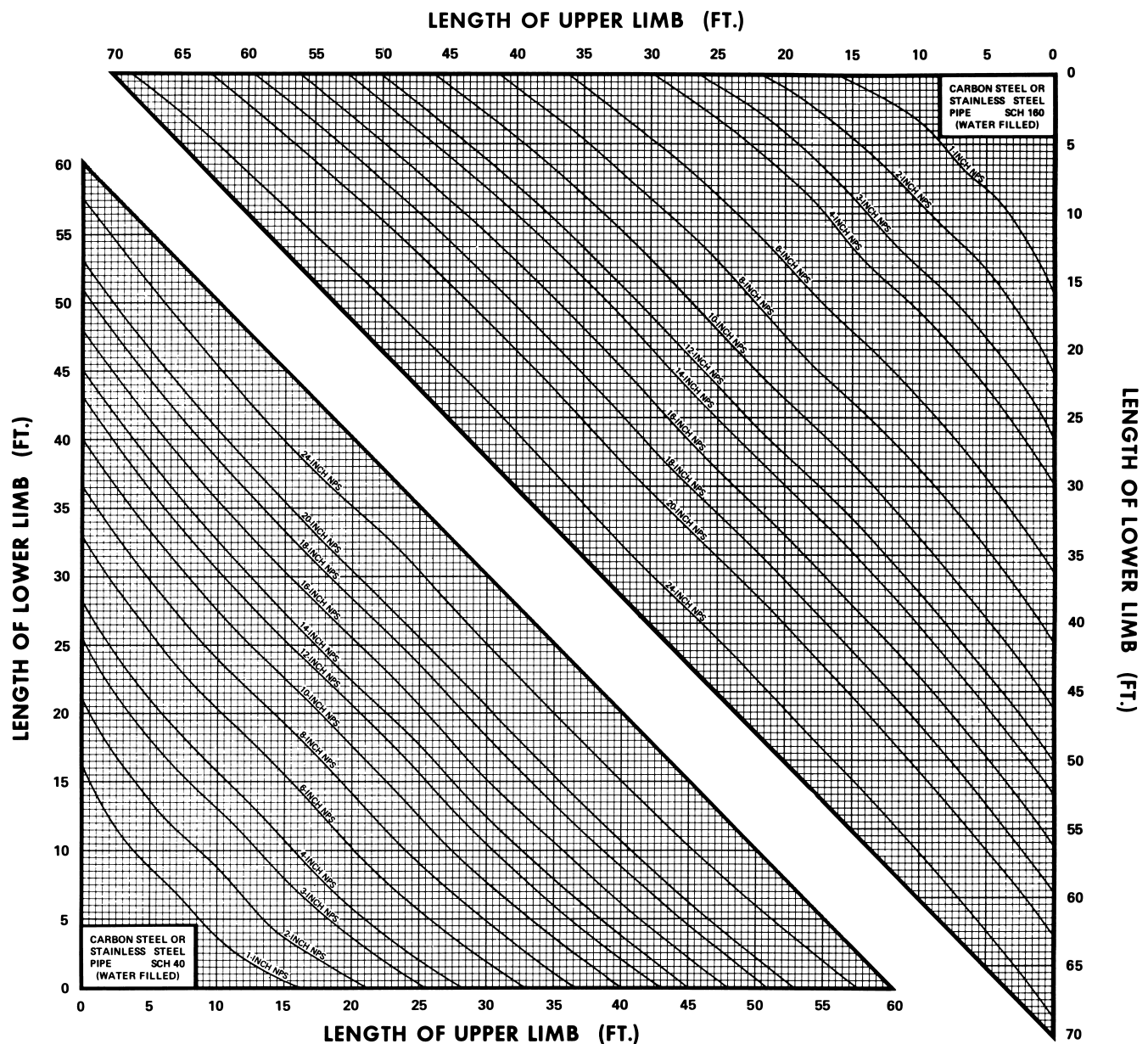
### UPPER CHART: SCH 80, ALUMINUM

# SPANS OF HORIZONTAL PIPE WITH 3-FT. RISE OR FALL



## CHARTS S-2

THESE CHARTS GIVE THE MAXIMUM LENGTH PERMISSIBLE FOR EITHER HORIZONTAL LIMB IN THE PIPING ARRANGEMENT SHOWN, AND APPLY WHEN THE SPAN INCLUDING THE RISE OR FALL IS CONTINUOUS WITH TWO OR MORE STRAIGHT SPANS AT EACH END.

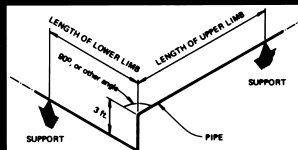


**LOWER CHART:**  
**SCH 40, STEEL**

Data for water-filled steel pipe are based on a maximum bending stress of 4000 PSI, occurring at supports and due to bending by the weight of pipe plus water: applied stresses may increase the resultant tensile stress. These data apply to carbon-steel and stainless-steel pipe having a tensile modulus of elasticity of 29,000,000 PSI. For water-filled aluminum pipe, spans are similarly based on a stress of 2000 PSI and a modulus of 10,000,000 PSI.

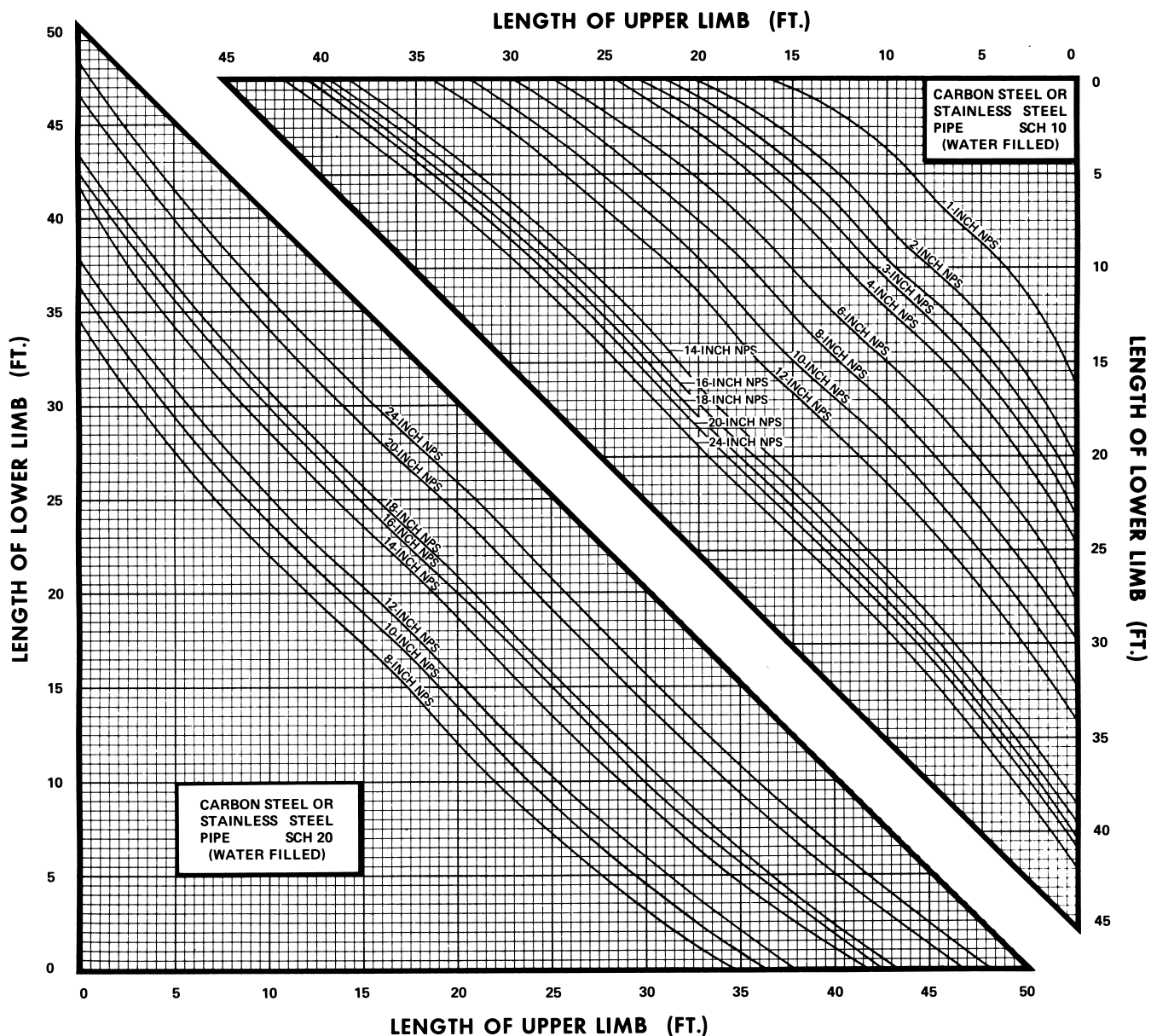
**UPPER CHART:**  
**SCH 160, STEEL**

# SPANS OF HORIZONTAL PIPE WITH 3-FT. RISE OR FALL



## CHARTS S-2

THESE CHARTS GIVE THE MAXIMUM LENGTH PERMISSIBLE FOR EITHER HORIZONTAL LIMB IN THE PIPING ARRANGEMENT SHOWN, AND APPLY WHEN THE SPAN INCLUDING THE RISE OR FALL IS CONTINUOUS WITH TWO OR MORE STRAIGHT SPANS AT EACH END.



**LOWER CHART:**  
**SCH 20, STEEL**

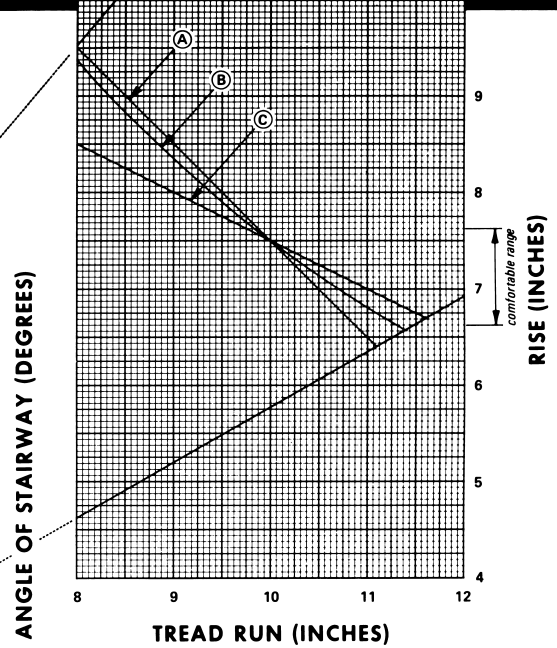
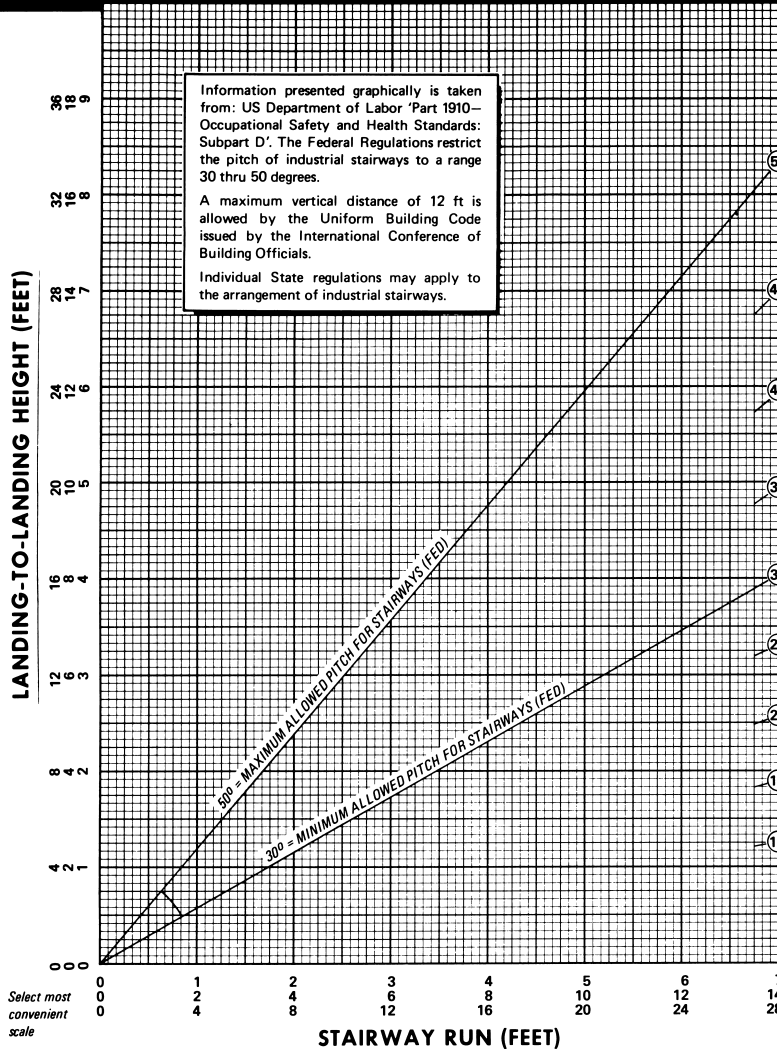
Data for water-filled steel pipe are based on a maximum bending stress of 4000 PSI, occurring at supports and due to bending by the weight of pipe plus water; applied stresses may increase the resultant tensile stress. These data apply to carbon-steel and stainless-steel pipe having a tensile modulus of elasticity of 29,000,000 PSI. For water-filled aluminum pipe, spans are similarly based on a stress of 2000 PSI and a modulus of 10,000,000 PSI.

**UPPER CHART:**  
**SCH 10, STEEL**

# STAIRWAYS

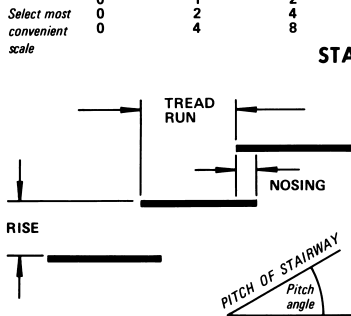
## FEDERAL REGULATIONS FOR FIXED INDUSTRIAL STAIRWAYS

## CHART S-3



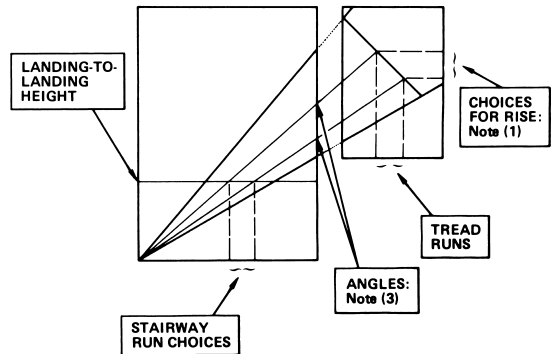
### KEY

- (A)  $R = \text{RISE IN INCHES}$ ,  $T = \text{TREAD RUN IN INCHES}$ . LINE (A) IS BASED ON:  
 $R + T = 17\frac{1}{2}$ .
- THE FEDERAL REGULATIONS SUGGEST LINE (A) COMBINATIONS OF RISE AND TREAD RUN
- (B) THIS LINE IS BASED ON  $R \times T = 75$
- (C) THIS LINE IS BASED ON  $2R + T = 25$



### NOTES

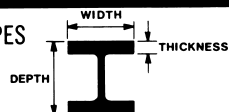
- LANDING-TO-LANDING HEIGHT IS USUALLY ESTABLISHED. DIVIDE THIS HEIGHT INTO WHOLE NUMBERS OF RISES.
- SELECT ONE OF THE LINES A, B, OR C (OR OTHER COMPANY PREFERENCE) AND MARK VALUES FOR RISES ON THE LINE.
- CONSTRUCT LINES FROM THESE POINTS TO THE BOTTOM LEFT CORNER OF THE LARGER GRAPH. THIS GIVES THE CHOICE OF ANGLES AND RUNS FOR THE STAIRWAY.



# STRUCTURAL STEEL

DECIMAL DIMENSIONS  
ARE NOMINAL - IN  
MULTIPLES OF 1/16"

## W SHAPES



# TABLE S-4

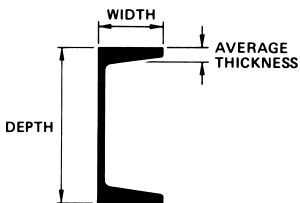
| DESIGNATION<br>NOM. SIZE<br>x lb/ft | DEPTH | WIDTH | THICK | DESIGNATION<br>NOM. SIZE<br>x lb/ft | DEPTH | WIDTH | THICK | DESIGNATION<br>NOM. SIZE<br>x lb/ft | DEPTH | WIDTH | THICK | DESIGNATION<br>NOM. SIZE<br>x lb/ft | DEPTH | WIDTH | THICK |
|-------------------------------------|-------|-------|-------|-------------------------------------|-------|-------|-------|-------------------------------------|-------|-------|-------|-------------------------------------|-------|-------|-------|
| DIMENSIONS: inches                  |       |       |       | DIMENSIONS: inches                  |       |       |       | DIMENSIONS: inches                  |       |       |       | DIMENSIONS: inches                  |       |       |       |
| W 36                                |       |       |       | W 21                                |       |       |       | W 14                                |       |       |       | W 12                                |       |       |       |
| W 36 x 300                          | 36.75 | 16.62 | 1.69  | W 21 x 147                          | 22.00 | 12.50 | 1.12  | x 342                               | 17.50 | 16.38 | 2.50  | x 50                                | 12.25 | 8.12  | 0.62  |
| x 280                               | 36.50 | 16.62 | 1.56  | x 142                               | 21.50 | 13.12 | 1.12* | x 342                               | 17.50 | 16.38 | 2.44* | x 45                                | 12.00 | 8.00  | 0.56  |
| x 260                               | 36.25 | 16.50 | 1.44  | x 132                               | 21.88 | 12.50 | 1.06  | x 320                               | 16.75 | 16.75 | 2.06* | x 40                                | 12.00 | 8.00  | 0.50  |
| x 245                               | 36.12 | 16.50 | 1.38  | x 127                               | 21.25 | 13.00 | 1.00* | x 314                               | 17.25 | 16.25 | 2.31* | x 36                                | 12.25 | 6.62  | 0.56* |
| x 245                               | 36.00 | 16.50 | 1.38* | x 122                               | 21.62 | 12.38 | 0.94  | x 311                               | 17.12 | 16.25 | 2.25  | x 35                                | 12.50 | 6.50  | 0.50  |
| x 230                               | 35.88 | 16.50 | 1.25  | x 112                               | 21.00 | 13.00 | 0.88* | x 287                               | 16.75 | 16.12 | 2.06* | x 31                                | 12.12 | 6.50  | 0.44* |
| x 210                               | 36.75 | 12.12 | 1.38  | x 111                               | 21.50 | 12.38 | 0.88  | x 283                               | 16.75 | 16.12 | 2.06  | x 30                                | 12.38 | 6.50  | 0.44  |
| x 194                               | 36.50 | 12.12 | 1.25  | x 101                               | 21.38 | 12.25 | 0.81  | x 264                               | 16.50 | 16.00 | 1.94* | x 27                                | 12.00 | 6.50  | 0.38* |
| x 182                               | 36.38 | 12.12 | 1.19  | x 96                                | 21.12 | 9.00  | 0.94* | x 257                               | 16.38 | 16.00 | 1.88  | x 26                                | 12.25 | 6.50  | 0.38  |
| x 170                               | 36.12 | 12.00 | 1.12  | x 93                                | 21.62 | 8.38  | 0.94  | x 246                               | 16.25 | 16.00 | 1.81* | x 22                                | 12.25 | 4.00  | 0.44  |
| x 160                               | 36.00 | 12.00 | 1.00  | x 83                                | 21.38 | 8.38  | 0.81  | x 237                               | 16.12 | 15.88 | 1.75* | x 19                                | 12.12 | 4.00  | 0.38  |
| x 150                               | 35.88 | 12.00 | 0.94  | x 82                                | 20.88 | 9.00  | 0.81* | x 233                               | 16.00 | 15.88 | 1.75  | x 16.5                              | 12.00 | 4.00  | 0.25* |
| x 135                               | 35.50 | 12.00 | 0.81  | x 73                                | 21.25 | 8.25  | 0.75  | x 228                               | 16.00 | 15.88 | 1.69* | x 16                                | 12.00 | 4.00  | 0.25  |
|                                     |       |       |       | x 68                                | 21.12 | 8.25  | 0.69  | x 219                               | 15.88 | 15.88 | 1.62* | x 14                                | 11.88 | 4.00  | 0.25  |
|                                     |       |       |       | x 62                                | 21.00 | 8.25  | 0.62  | x 211                               | 15.75 | 15.75 | 1.56  |                                     |       |       |       |
|                                     |       |       |       | x 57                                | 21.00 | 6.50  | 0.62  | x 202                               | 15.62 | 15.75 | 1.50* | W 10                                |       |       |       |
|                                     |       |       |       | x 55                                | 20.75 | 8.25  | 0.50* | x 193                               | 15.50 | 15.75 | 1.44  | W 10 x 112                          | 11.38 | 10.38 | 1.25  |
|                                     |       |       |       | x 50                                | 20.88 | 6.50  | 0.56  | x 184                               | 15.38 | 15.62 | 1.38* | x 100                               | 11.12 | 10.38 | 1.12  |
|                                     |       |       |       | x 49                                | 20.88 | 6.50  | 0.56* | x 176                               | 15.25 | 15.62 | 1.31  | x 89                                | 10.88 | 10.25 | 1.00* |
|                                     |       |       |       | x 44                                | 20.62 | 6.50  | 0.44  | x 167                               | 15.12 | 15.62 | 1.25* | x 88                                | 10.88 | 10.25 | 1.00  |
|                                     |       |       |       | W 18                                |       |       |       | x 159                               | 15.00 | 15.62 | 1.19  | x 77                                | 10.62 | 10.25 | 0.88  |
|                                     |       |       |       | W 18 x 119                          | 19.00 | 11.25 | 1.06  | x 158                               | 15.00 | 15.50 | 1.19* | x 72                                | 10.50 | 10.12 | 0.81* |
|                                     |       |       |       | x 114                               | 18.50 | 11.88 | 1.00* | x 150                               | 14.88 | 15.50 | 1.12* | x 68                                | 10.38 | 10.12 | 0.75  |
|                                     |       |       |       | x 106                               | 18.75 | 11.25 | 0.94  | x 145                               | 14.75 | 15.50 | 1.06  | x 66                                | 10.38 | 10.12 | 0.75* |
|                                     |       |       |       | x 105                               | 18.38 | 11.75 | 0.94* | x 142                               | 14.75 | 15.50 | 1.06* | x 60                                | 10.25 | 10.12 | 0.69  |
|                                     |       |       |       | x 97                                | 18.62 | 11.12 | 0.88  | x 136                               | 14.75 | 14.75 | 1.06* | x 54                                | 10.12 | 10.00 | 0.62  |
|                                     |       |       |       | x 96                                | 18.12 | 11.75 | 0.81* | x 132                               | 14.62 | 14.75 | 1.00  | x 49                                | 10.00 | 10.00 | 0.56  |
|                                     |       |       |       | x 86                                | 18.38 | 11.12 | 0.75  | x 127                               | 14.62 | 14.75 | 1.00* | x 45                                | 10.12 | 8.00  | 0.62  |
|                                     |       |       |       | x 85                                | 18.38 | 8.88  | 0.94* | x 120                               | 14.50 | 14.62 | 0.94  | x 39                                | 9.88  | 8.00  | 0.50  |
|                                     |       |       |       | x 77                                | 18.12 | 8.75  | 0.81* | x 119                               | 14.50 | 14.62 | 0.94* | x 39                                | 10.00 | 8.00  | 0.50* |
|                                     |       |       |       | x 76                                | 18.25 | 11.00 | 0.69  | x 111                               | 14.38 | 14.62 | 0.88* | x 33                                | 9.75  | 8.00  | 0.44  |
|                                     |       |       |       | x 71                                | 18.50 | 7.62  | 0.81  | x 109                               | 14.38 | 14.62 | 0.88  | x 30                                | 10.50 | 5.75  | 0.50  |
|                                     |       |       |       | x 70                                | 18.00 | 8.75  | 0.75* | x 103                               | 14.25 | 14.62 | 0.81* | x 29                                | 10.25 | 5.75  | 0.50* |
|                                     |       |       |       | x 65                                | 18.38 | 7.62  | 0.75  | x 99                                | 14.12 | 14.62 | 0.75  | x 26                                | 10.38 | 5.75  | 0.44  |
|                                     |       |       |       | x 64                                | 17.88 | 8.75  | 0.69* | x 95                                | 14.12 | 14.50 | 0.75* | x 25                                | 10.12 | 5.75  | 0.44* |
|                                     |       |       |       | x 60                                | 18.25 | 7.50  | 0.69  | x 90                                | 14.00 | 14.50 | 0.69  | x 22                                | 10.12 | 5.75  | 0.38  |
|                                     |       |       |       | x 55                                | 18.12 | 7.50  | 0.62  | x 87                                | 14.00 | 14.50 | 0.69* | x 21                                | 9.88  | 5.75  | 0.31* |
|                                     |       |       |       | x 50                                | 18.00 | 7.50  | 0.56  | x 84                                | 14.12 | 12.00 | 0.75* | x 19                                | 10.25 | 4.00  | 0.38  |
|                                     |       |       |       | x 46                                | 18.00 | 6.00  | 0.62  | x 82                                | 14.25 | 10.12 | 0.88  | x 17                                | 10.12 | 4.00  | 0.31  |
|                                     |       |       |       | x 45                                | 17.88 | 7.50  | 0.50* | x 78                                | 14.00 | 12.00 | 0.69* | x 15                                | 10.00 | 4.00  | 0.25  |
|                                     |       |       |       | x 40                                | 17.88 | 6.00  | 0.50  | x 74                                | 14.12 | 10.12 | 0.81  | x 12                                | 9.88  | 4.00  | 0.19  |
|                                     |       |       |       | x 35                                | 17.75 | 6.00  | 0.44  | x 74                                | 14.25 | 10.12 | 0.81* | x 11.5                              | 9.88  | 4.00  | 0.19* |
|                                     |       |       |       | W 16                                |       |       |       | x 68                                | 14.00 | 10.00 | 0.75  |                                     |       |       |       |
|                                     |       |       |       | W 16 x 100                          | 17.00 | 10.38 | 1.00  | x 68                                | 14.00 | 10.00 | 0.69* | W 8                                 |       |       |       |
|                                     |       |       |       | x 96                                | 16.38 | 11.50 | 0.88* | x 61                                | 13.88 | 10.00 | 0.62  | W 8 x 67                            | 9.00  | 8.25  | 0.94  |
|                                     |       |       |       | x 89                                | 16.75 | 10.38 | 0.88  | x 53                                | 13.88 | 8.00  | 0.69  | x 58                                | 8.75  | 8.25  | 0.81  |
|                                     |       |       |       | x 88                                | 16.12 | 11.50 | 0.81* | x 53                                | 14.00 | 8.00  | 0.69* | x 48                                | 8.50  | 8.12  | 0.69  |
|                                     |       |       |       | x 78                                | 16.38 | 8.62  | 0.88* | x 48                                | 13.75 | 8.00  | 0.62  | x 40                                | 8.25  | 8.12  | 0.56  |
|                                     |       |       |       | x 77                                | 16.50 | 10.25 | 0.75  | x 48                                | 13.75 | 8.00  | 0.56* | x 35                                | 8.12  | 8.00  | 0.50  |
|                                     |       |       |       | x 71                                | 16.12 | 8.50  | 0.81* | x 43                                | 13.62 | 8.00  | 0.50  | x 31                                | 8.00  | 8.00  | 0.44  |
|                                     |       |       |       | x 67                                | 16.38 | 10.25 | 0.69  | x 38                                | 14.12 | 6.75  | 0.50  | x 28                                | 8.00  | 6.50  | 0.44  |
|                                     |       |       |       | x 64                                | 16.00 | 8.50  | 0.69* | x 34                                | 14.00 | 6.75  | 0.44  | x 24                                | 7.88  | 6.50  | 0.38  |
|                                     |       |       |       | x 58                                | 15.88 | 8.50  | 0.62* | x 30                                | 13.88 | 6.75  | 0.38  | x 21                                | 8.25  | 5.25  | 0.38  |
|                                     |       |       |       | x 57                                | 16.38 | 7.12  | 0.69  | x 26                                | 13.88 | 5.00  | 0.44  | x 20                                | 8.12  | 5.25  | 0.38* |
|                                     |       |       |       | x 50                                | 16.25 | 7.12  | 0.62  | x 22                                | 13.75 | 5.00  | 0.31  | x 18                                | 8.12  | 5.25  | 0.31  |
|                                     |       |       |       | x 45                                | 16.12 | 7.00  | 0.56  | W 12                                |       |       |       | x 17                                | 8.00  | 5.25  | 0.31* |
|                                     |       |       |       | x 40                                | 16.00 | 7.00  | 0.50  | W 12 x 336                          | 16.88 | 13.38 | 2.94  | x 15                                | 8.12  | 4.00  | 0.31  |
|                                     |       |       |       | x 36                                | 15.88 | 7.00  | 0.44  | x 305                               | 16.38 | 13.25 | 2.69  | x 13                                | 8.00  | 4.00  | 0.25  |
|                                     |       |       |       | x 31                                | 15.88 | 5.50  | 0.44  | x 279                               | 15.88 | 13.12 | 2.50  | x 10                                | 7.88  | 4.00  | 0.19  |
|                                     |       |       |       | x 26                                | 15.75 | 5.50  | 0.38  | x 252                               | 15.38 | 13.00 | 2.25  | W 6                                 |       |       |       |
|                                     |       |       |       | x 26                                | 15.62 | 5.50  | 0.38* | x 230                               | 15.00 | 12.88 | 2.06  | W 6 x 25                            | 6.38  | 6.12  | 0.44  |
|                                     |       |       |       | W 14                                |       |       |       | x 210                               | 14.75 | 12.75 | 1.88  | x 20                                | 6.25  | 6.00  | 0.38  |
|                                     |       |       |       | W 14 x 730                          | 22.38 | 17.88 | 4.94  | x 190                               | 14.38 | 12.62 | 1.75  | x 16                                | 6.25  | 4.00  | 0.38  |
|                                     |       |       |       | x 730                               | 22.50 | 17.88 | 4.94* | x 170                               | 14.00 | 12.62 | 1.56  | x 15.5                              | 6.00  | 6.00  | 0.25* |
|                                     |       |       |       | x 665                               | 21.62 | 17.62 | 4.50  | x 161                               | 13.88 | 12.50 | 1.50* | x 15                                | 6.00  | 6.00  | 0.25  |
|                                     |       |       |       | x 605                               | 20.88 | 17.38 | 4.19  | x 152                               | 13.75 | 12.50 | 1.38  | x 12                                | 6.00  | 4.00  | 0.25  |
|                                     |       |       |       | x 605                               | 21.00 | 17.38 | 4.19* | x 136                               | 13.38 | 12.38 | 1.25  | x 9                                 | 5.88  | 4.00  | 0.19  |
|                                     |       |       |       | x 550                               | 20.25 | 17.25 | 3.81  | x 133                               | 13.38 | 12.38 | 1.25* | x 8.5                               | 5.88  | 4.00  | 0.19* |
|                                     |       |       |       | x 500                               | 19.62 | 17.00 | 3.50  | x 120                               | 13.12 | 12.38 | 1.12  | W 5                                 |       |       |       |
|                                     |       |       |       | x 455                               | 19.00 | 16.88 | 3.19  | x 106                               | 12.88 | 12.25 | 1.00  | W 5 x 19                            | 5.12  | 5.00  | 0.44  |
|                                     |       |       |       | x 426                               | 18.62 | 16.75 | 3.06  | x 99                                | 12.75 | 12.25 | 0.94* | x 18.5                              | 5.12  | 5.00  | 0.44* |
|                                     |       |       |       | x 426                               | 18.75 | 16.75 | 3.06* | x 96                                | 12.75 | 12.12 | 0.88  | x 16                                | 5.00  | 5.00  | 0.38  |
|                                     |       |       |       | x 398                               | 18.25 | 16.62 | 2.88  | x 92                                | 12.62 | 12.12 | 0.88* | W 4                                 |       |       |       |
|                                     |       |       |       | x 398                               | 18.25 | 16.62 | 2.81* | x 87                                | 12.50 | 12.12 | 0.81  | W 4 x 13                            | 4.12  | 4.00  | 0.38  |
|                                     |       |       |       | x 370                               | 17.88 | 16.50 | 2.69  | x 85                                | 12.50 | 12.12 | 0.81* | W 3                                 |       |       |       |
|                                     |       |       |       | x 370                               | 18.00 | 16.50 | 2.69* | x 79                                | 12.38 | 12.12 | 0.75  | W                                   |       |       |       |
|                                     |       |       |       |                                     |       |       |       | x 72                                | 12.25 | 12.00 | 0.69  |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       | x 65                                | 12.12 | 12.00 | 0.62  |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       | x 58                                | 12.25 | 10.00 | 0.62  |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       | x 53                                | 12.00 | 10.00 | 0.56  |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |
|                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |                                     |       |       |       |

## CHANNEL DATA

AMERICAN STANDARD

| DESIGNATION<br>Depth (nom)<br>x wgt lb/ft | DIMENSIONS IN INCHES             |                              |                              |
|---|----------------------------------|------------------------------|------------------------------|
|   | DEPTH                            | WIDTH                        | THICK                        |
| C 15x50<br>x40<br>x33.9                   | 15.00<br>15.00<br>15.00          | 3.75<br>3.50<br>3.38         | 0.62<br>0.62<br>0.62         |
| C 12x30<br>x25<br>x20.7                   | 12.00<br>12.00<br>12.00          | 3.12<br>3.00<br>3.00         | 0.50<br>0.50<br>0.50         |
| C 10x30<br>x25<br>x20<br>x15.3            | 10.00<br>10.00<br>10.00<br>10.00 | 3.00<br>2.88<br>2.75<br>2.62 | 0.44<br>0.44<br>0.44<br>0.44 |
| C 9x20<br>x15<br>x13.4                    | 9.00<br>9.00<br>9.00             | 2.62<br>2.50<br>2.38         | 0.44<br>0.44<br>0.44         |
| C 8x18.75<br>x13.75<br>x11.5              | 8.00<br>8.00<br>8.00             | 2.50<br>2.38<br>2.25         | 0.38<br>0.38<br>0.38         |
| C 7x14.75<br>x12.25<br>x 9.8              | 7.00<br>7.00<br>7.00             | 2.25<br>2.25<br>2.12         | 0.38<br>0.38<br>0.38         |
| C 6x13<br>x10.5<br>x 8.2                  | 6.00<br>6.00<br>6.00             | 2.12<br>2.00<br>1.88         | 0.31<br>0.31<br>0.31         |
| C 5x 9<br>x 6.7                           | 5.00<br>5.00                     | 1.88<br>1.75                 | 0.31<br>0.31                 |
| C 4x 7.25<br>x 5.4                        | 4.00<br>4.00                     | 1.75<br>1.62                 | 0.31<br>0.31                 |
| C 3x 6<br>x 5<br>x 4.1                    | 3.00<br>3.00<br>3.00             | 1.62<br>1.50<br>1.38         | 0.25<br>0.25<br>0.25         |

### AMERICAN STANDARD CHANNELS



## ANGLE DATA

WEIGHTS IN POUNDS PER LINEAR FOOT

## TABLES S-5

| UNEQUAL LEGS    |  |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------|--|------|------|------|------|------|------|------|------|------|------|------|------|
| S I Z E         | T H I C K N E S S                      |      |      |      |      |      |      |      |      |      |      |      |      |
|                 | 1                                      | 7/8  | 3/4  | 5/8  | 9/16 | 1/2  | 7/16 | 3/8  | 5/16 | 1/4  | 3/16 | 1/8  |      |
| 9 x 4 x         |  |      |      | 26.3 | 23.8 | 21.3 |      |      |      |      |      |      |      |
| 8 x 6 x         | 44.2                                   | 39.1 | 33.8 | 28.5 | 25.7 | 23.0 | 20.2 |      |      |      |      |      |      |
| 8 x 4 x         | 37.4                                   |      | 28.7 |      | 21.9 | 19.6 |      |      |      |      |      |      |      |
| 7 x 4 x         |  |      | 26.2 | 22.1 |      | 17.9 |      | 13.6 |      |      |      |      |      |
| 6 x 4 x         |  | 27.2 | 23.6 | 20.0 | 18.1 | 16.2 | 14.3 | 12.3 | 10.3 |      |      |      |      |
| 6 x 3 1/2 x     |  |      |      |      |      | 15.3 |      | 11.7 | 9.8  |      |      |      |      |
| 5 x 3 1/2 x     |  |      | 19.8 | 16.8 |      | 13.6 | 12.0 | 10.4 | 8.7  | 7.0  |      |      |      |
| 5 x 3 x         |  |      |      | 15.7 |      | 12.8 | 11.3 | 9.8  | 8.2  | 6.6  |      |      |      |
| 4 x 3 1/2 x     |  |      |      | 14.7 |      | 11.9 | 10.6 | 9.1  | 7.7  | 6.2  |      |      |      |
| 4 x 3 x         |  |      |      | 13.6 |      | 11.1 | 9.8  | 8.5  | 7.2  | 5.8  |      |      |      |
| 3 1/2 x 3 x     |  |      |      |      |      | 10.2 | 9.1  | 7.9  | 6.6  | 5.4  |      |      |      |
| 3 1/2 x 2 1/2 x |  |      |      |      |      | 9.4  | 8.3  | 7.2  | 6.1  | 4.9  |      |      |      |
| 3 x 2 1/2 x     |  |      |      |      |      | 8.5  | 7.6  | 6.6  | 5.6  | 4.5  | 3.39 |      |      |
| 3 x 2 x         |  |      |      |      |      | 7.7  | 6.8  | 5.9  | 5.0  | 4.1  | 3.07 |      |      |
| 2 1/2 x 2 x     |  |      |      |      |      |      |      | 5.3  | 4.5  | 3.62 | 2.75 |      |      |
| 2 1/2 x 1 1/2 x |  |      |      |      |      |      |      |      | 3.92 | 3.19 | 2.44 |      |      |
| 2 x 1 1/2 x     | EXAMPLE DESIGNATION: L 2 x 1 1/2 x 1/4 |      |      |      |      |      |      |      |      |      | 2.77 | 2.12 | 1.44 |
| 2 x 1 1/4 x     |  |      |      |      |      |      |      |      |      | 2.55 | 1.96 |      |      |
| 1 3/4 x 1 1/4 x |  |      |      |      |      |      |      |      |      | 2.34 | 1.8  | 1.23 |      |

| EQUAL LEGS      |                                    |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| S I Z E         | T H I C K N E S S                  |      |      |      |      |      |      |      |      |      |      |      |      |
|                 | 1 1/8                              | 1    | 7/8  | 3/4  | 5/8  | 9/16 | 1/2  | 7/16 | 3/8  | 5/16 | 1/4  | 3/16 | 1/8  |
| 8 x 8 x         | 56.9                               | 51.0 | 45.0 | 38.9 | 32.7 | 29.6 | 26.4 |      |      |      |      |      |      |
| 6 x 6 x         |                                    | 37.4 | 33.1 | 28.7 | 24.2 | 21.9 | 19.6 | 17.2 | 14.9 | 12.4 |      |      |      |
| 5 x 5 x         |                                    |      | 27.2 | 23.6 | 20.0 |      | 16.2 | 14.3 | 12.3 | 10.3 |      |      |      |
| 4 x 4 x         |                                    |      |      | 18.5 | 15.7 |      | 12.8 | 11.3 | 9.8  | 8.2  | 6.6  |      |      |
| 3 1/2 x 3 1/2 x |                                    |      |      |      |      |      | 11.1 | 9.8  | 8.5  | 7.2  | 5.8  |      |      |
| 3 x 3 x         |                                    |      |      |      |      |      | 9.4  | 8.3  | 7.2  | 6.1  | 4.9  | 3.71 |      |
| 2 1/2 x 2 1/2 x |                                    |      |      |      |      |      | 7.7  |      | 5.9  | 5.0  | 4.1  | 3.07 |      |
| 2 x 2 x         |                                    |      |      |      |      |      |      |      | 4.7  | 3.92 | 3.19 | 2.44 | 1.65 |
| 1 3/4 x 1 3/4 x |                                    |      |      |      |      |      |      |      |      |      | 2.77 | 2.12 | 1.44 |
| 1 1/2 x 1 1/2   | EXAMPLE DESIGNATION: L 3 x 3 x 3/8 |      |      |      |      |      |      |      |      |      | 3.35 | 2.34 | 1.80 |
| 1 1/4 x 1 1/4 x |                                    |      |      |      |      |      |      |      |      |      | 1.92 | 1.48 | 1.01 |
| 1 x 1 x         |                                    |      |      |      |      |      |      |      |      |      | 1.49 | 1.16 | 0.80 |

# TUBE DATA

# TABLE T-1

REPRODUCED BY COURTESY OF STOCKHAM VALVES AND FITTINGS

The following dimensional data for copper tube conform to ASTM B-88, which specifies general requirements for Wrought Seamless Copper Alloy Pipe and Tube.

## TYPE K TUBE

Heavy wall thickness, hard or soft, is furnished for interior plumbing and underground service; steam and hot water heating systems; fuel oil lines; industrial process applications carrying liquids, air and gases; air conditioning, refrigeration, and low pressure hydraulic lines. Hard copper tube is used for gas service lines because its rigidity eliminates traps caused by sagging lines.

| Nominal Size | NOMINAL DIMENSIONS        |                          |                         | THEORETICAL AREAS BASED ON NOMINAL DIMENSIONS |   |   | Theoretical Weight (Pounds Per Foot) |
|--------------|---------------------------|--------------------------|-------------------------|---|---|---|--------------------------------------|
|              | Outside Diameter (Inches) | Inside Diameter (Inches) | Wall Thickness (Inches) | Cross Sectional Area of Bore (Sq. Inches)     | External Surface (Sq. Ft. Per Lin. Ft.) | Internal Surface (Sq. Ft. Per Lin. Ft.) |                                      |
| 1/4          | .375                      | .305                     | .035                    | .073  | .098                                    | .080                                    | 0.145                                |
| 3/8          | .500                      | .402                     | .049                    | .127  | .131                                    | .105                                    | 0.269                                |
| 1/2          | .625                      | .527                     | .049                    | .218  | .164                                    | .138                                    | 0.344                                |
| 3/4          | .875                      | .745                     | .065                    | .436  | .229                                    | .195                                    | 0.641                                |
| 1            | 1.125                     | .995                     | .065                    | .778  | .294                                    | .261                                    | 0.839                                |
| 1 1/4        | 1.375                     | 1.245                    | .065                    | 1.22  | .360                                    | .326                                    | 1.04                                 |
| 1 1/2        | 1.625                     | 1.481                    | .072                    | 1.72  | .425                                    | .388                                    | 1.36                                 |
| 2            | 2.125                     | 1.959                    | .083                    | 3.01  | .556                                    | .513                                    | 2.06                                 |
| 2 1/2        | 2.625                     | 2.435                    | .095                    | 4.66  | .687                                    | .638                                    | 2.93                                 |
| 3            | 3.125                     | 2.907                    | .109                    | 6.64  | .818                                    | .761                                    | 4.00                                 |

## TYPE L TUBE

Medium wall thickness, hard or soft, is used for medium pressure interior plumbing and for steam and hot water house-heating systems, panel heating, plumbing vent systems, industrial and process applications.

| Nominal Size | NOMINAL DIMENSIONS        |                          |                         | THEORETICAL AREAS BASED ON NOMINAL DIMENSIONS |   |   | Theoretical Weight (Pounds Per Foot) |
|--------------|---------------------------|--------------------------|-------------------------|---|---|---|--------------------------------------|
|              | Outside Diameter (Inches) | Inside Diameter (Inches) | Wall Thickness (Inches) | Cross Sectional Area of Bore (Sq. Inches)     | External Surface (Sq. Ft. Per Lin. Ft.) | Internal Surface (Sq. Ft. Per Lin. Ft.) |                                      |
| 1/4          | .375                      | .315                     | .030                    | .078  | .098                                    | .082                                    | 0.126                                |
| 3/8          | .500                      | .430                     | .035                    | .145  | .131                                    | .113                                    | 0.198                                |
| 1/2          | .625                      | .545                     | .040                    | .233  | .164                                    | .143                                    | 0.285                                |
| 3/4          | .875                      | .785                     | .045                    | .484  | .229                                    | .206                                    | 0.455                                |
| 1            | 1.125                     | 1.025                    | .050                    | .825  | .294                                    | .268                                    | 0.655                                |
| 1 1/4        | 1.375                     | 1.265                    | .055                    | 1.26  | .360                                    | .331                                    | 0.884                                |
| 1 1/2        | 1.625                     | 1.505                    | .060                    | 1.78  | .425                                    | .394                                    | 1.14                                 |
| 2            | 2.125                     | 1.985                    | .070                    | 3.09  | .556                                    | .520                                    | 1.75                                 |
| 2 1/2        | 2.625                     | 2.465                    | .080                    | 4.77  | .687                                    | .645                                    | 2.48                                 |
| 3            | 3.125                     | 2.945                    | .090                    | 6.81  | .818                                    | .771                                    | 3.33                                 |

## TYPE M TUBE

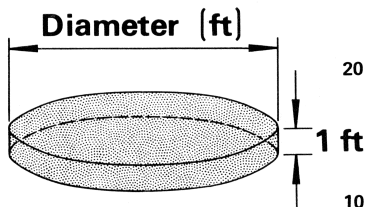
Light wall thickness, hard only, furnished for applications requiring little or no pressure or tensions on the lines.

| Nominal Size | NOMINAL DIMENSIONS        |                          |                         | THEORETICAL AREAS BASED ON NOMINAL DIMENSIONS |   |   | Theoretical Weight (Pounds Per Foot) |
|--------------|---------------------------|--------------------------|-------------------------|---|---|---|--------------------------------------|
|              | Outside Diameter (Inches) | Inside Diameter (Inches) | Wall Thickness (Inches) | Cross Sectional Area of Bore (Sq. Inches)     | External Surface (Sq. Ft. Per Lin. Ft.) | Internal Surface (Sq. Ft. Per Lin. Ft.) |                                      |
| 1 1/4        | 1.375                     | 1.291                    | .042                    | 1.31  | .360                                    | .338                                    | 0.682                                |
| 1 1/2        | 1.625                     | 1.527                    | .049                    | 1.83  | .425                                    | .400                                    | 0.940                                |
| 2            | 2.125                     | 2.009                    | .058                    | 3.17  | .556                                    | .526                                    | 1.460                                |
| 2 1/2        | 2.625                     | 2.495                    | .065                    | 4.89  | .687                                    | .653                                    | 2.030                                |
| 3            | 3.125                     | 2.981                    | .072                    | 6.98  | .818                                    | .780                                    | 2.680                                |

# TANK & VESSEL VOLUMES

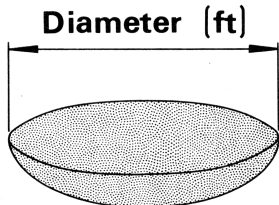
## CHART T-2

### TANK & VESSEL VOLUMES



Volume per foot ..... Line A

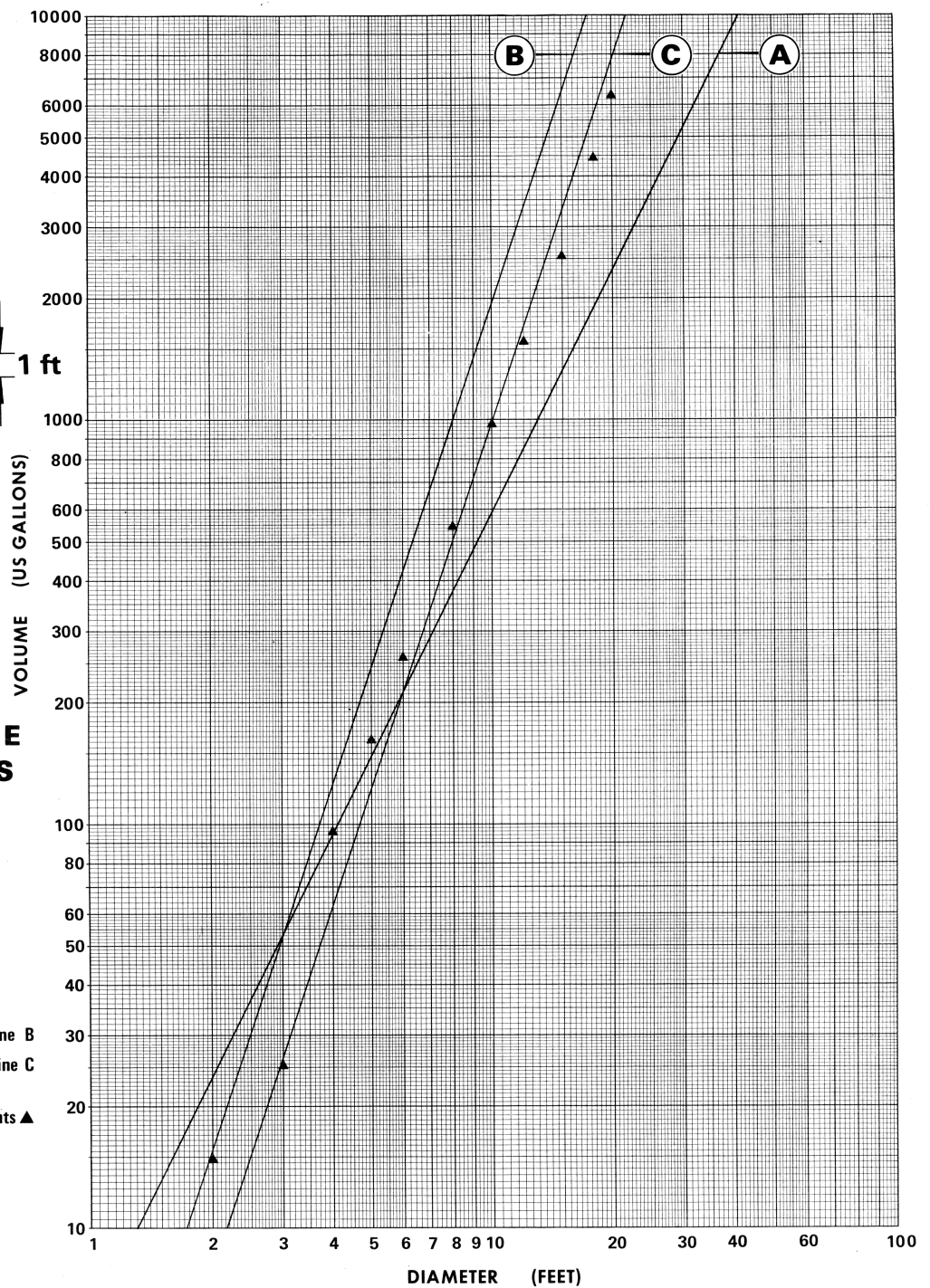
### INTERNAL VOLUME OF VESSEL HEADS



Hemispheric Head ..... Line B

Elliptic Head ..... Line C  
(ASME "Ellipsoidal")

Flanged & Dished Head ..... Points ▲  
(ASME "Torispherical")



# VALVE DATA - RUN LENGTHS

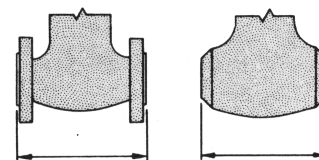
DIMENSIONS IN INCHES

## TABLE V-1

| FLANGE CLASS   |             | NOMINAL PIPE SIZE [ NPS ] |       |       |       |       |       |       |       |       |       |       |       |       |
|--|-------------|---------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|  |             | 2                         | 2 1/2 | 3     | 4     | 6     | 8     | 10    | 12    | 14    | 16    | 18    | 20    | 24    |
| STEEL GATE VALVES<br>SOLID WEDGE & DOUBLE-DISC (SPLIT-WEDGE) | FLANGED 150 | 7                         | 7.5   | 8     | 9     | 10.50 | 11.50 | 13    | 14    | 15    | 16    | 17    | 18    | 20    |
|  | BEVELED 150 | 8.5                       | 9.5   | 11.12 | 12    | 15.88 | 16.50 | 18    | 19.75 | 22.50 | 24    | 26    | 28    | 32    |
|  | 300         | 8.5                       | 9.5   | 11.12 | 12    | 15.88 | 16.50 | 18    | 19.75 | 30    | 33    | 36    | 39    | 45    |
|  | 600         | 11.50                     | 13    | 14    | 17    | 22    | 26    | 31    | 33    | 35    | 39    | 43    | 47    | 55    |
|  | 900         | 14.50                     | 16.50 | 15    | 18    | 24    | 29    | 33    | 38    | 40.50 | 44.50 | 48    | 52    | 61    |
|  | 1500        | 14.50                     | 16.50 | 18.50 | 21.50 | 27.75 | 32.75 | 39    | 44.50 | 49.50 | 54.50 | 60.50 | 65.50 | 76.50 |
|  | 2500        | 17.75                     | 20    | 22.75 | 26.50 | 36    | 40.25 | 50    | 56    |       |       |       |       |       |
|  |             | 150                       | 8     | 8.5   | 9.5   | 11.50 | 16    | 19.50 | 24.50 | 27.50 |       |       |       |       |
| STEEL GLOBE VALVES<br>LIFT CHECK VALVES                      | 300         | 10.50                     | 11.50 | 12.50 | 14    | 17.50 | 22    | 24.50 | 28    |       |       |       |       |       |
|  | 600         | 11.50                     | 13    | 14    | 17    | 22    | 26    | 31    | 33    |       |       |       |       |       |
|  | 900         | 14.50                     | 16.50 | 15    | 18    | 24    | 29    | 33    | 38    |       |       |       |       |       |
|  | 1500        | 14.50                     | 16.50 | 18.50 | 21.50 | 27.75 | 32.75 | 39    | 44.50 |       |       |       |       |       |
|  | 2500        | 17.75                     | 20    | 22.75 | 26.50 | 36    | 40.25 | 50    | 56    |       |       |       |       |       |
|  |             |                           |       |       |       |       |       |       |       |       |       |       |       |       |
| SWING CHECK VALVES<br>TILTING DISC CHECK VALVES              | T-D 150     | 8                         | 8.5   | 9.5   | 11.50 | 14    | 19.50 | 24.50 | 27.50 |       |       |       |       |       |
|  | T-D 300     | 10.50                     | 11.50 | 12.50 | 14    | 17.50 | 21    | 24.50 | 28    |       |       |       |       |       |
|  | T-D 600     | 11.50                     | 13    | 14    | 17    | 22    | 26    | 31    | 33    |       |       |       |       |       |
|  | T-D 900     | -                         | -     | 15    | 18    | 24    | 29    | 33    | 38    |       |       |       |       |       |
|  | T-D 1500    | 14.50                     | 16.50 | 18.50 | 21.50 | 27.75 | 32.75 | 39    | -     |       |       |       |       |       |
|  | 2500        | 17.75                     | 20    | 22.75 | 26.50 | 36    | 40.25 | 50    | 56    |       |       |       |       |       |

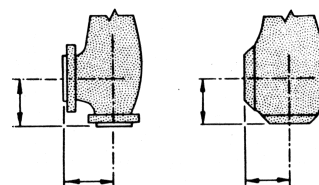
### NOTES

DIMENSIONS IN THIS TABLE CONFORM TO ANSI B16.10 AND APPLY TO FLANGED VALVES AND VALVES WITH ENDS BEVELLED FOR WELDING AS SHOWN:



Tabled Dimension

FOR FLANGED VALVES THE TABLED DIMENSION INCLUDES ALLOWANCE FOR BOTH RAISED FACES OF THE VALVE. FOR CLASSES 150 AND 300 VALVES, 0.06-inch HAS BEEN INCLUDED FOR EACH RAISED FACE AND FOR VALVES OF CLASS 600 AND ABOVE, 0.25-inch HAS BEEN INCLUDED FOR EACH RAISED FACE.



Half Tabled Dimension

FOR ANGLE GLOBE & ANGLE LIFT-CHECK VALVES, HALVE THE TABLED DIMENSION TO OBTAIN CENTER-TO-FACE DIMENSIONS.

# WEIGHTS OF PIPING

# TABLES W-1

## NOTES

A factor in the design of piping supports is the weight of the piping to be supported. Calculation of the loadings involve the weights of pipe, fittings, flanges, valves, insulation, the conveyed fluid, and other related items that are also to be supported as part of the piping system.

Tables show weights of piping components. Data are subject to variation from manufacturing tolerances.

### PIPE

For Schedule numbers, Manufacturers' weights (traditional designations: STD, XS, etc.), weight per unit length, weight filled with water, thickness of wall - refer to Tables P-1.

### VALVES

Weights for valves do not include weights of powered operators or other devices specified for particular valves. Weights shown for valves in these tables are from data available as indicated from the Henry Vogt Machine Co. and from the Crane Company. Information herein is not intended to indicate the complete range of valves available from either manufacturer. Weights shown are for valves having conventional ports.

As valve features vary between manufacturers, actual weights of valves should be obtained from the specified manufacturer or supplier.

### INSULATION

Weights of insulation are shown for both calcium silicate and for conventional 85% magnesia (alone or in combination with diatomaceous silica). The assumed densities are 11 pounds per cubic foot for calcium silicate and 85% magnesia, and 21 pounds per cubic foot for diatomaceous silica.

Insulation weights assumed include estimated weights of canvas, cement, paint, wire and bands, but not weatherproofing or other special protection. Pipe coverings of other compositions will have different densities. Data for insulation are based on conventional thickness recommendations and may not correspond with insulation specifications for a particular project.

### UNITS OF WEIGHT

Weights in the following tables are in pounds - avoirdupois

# TABLES W-1

# WEIGHTS OF PIPING

NOMINAL PIPE SIZE: 1"

NOMINAL PIPE SIZE: 1 1/2"

|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
|--|---|------------|----------------|------------|------------|------------|----------------|------------|------------|------------|--------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| F<br>I<br>T<br>I<br>N<br>G<br>S                | FORGED STEEL<br>SOCKET WELD:                | 3000       | PRESSURE CLASS |            |            |            | PRESSURE CLASS |            |            |            | 3000         | 6000       | 9000       |            |            |            |            |            |            |            |              |
|  | 90 ELBOW                                    | 1.00       | 2.35           |            |            |            | 2.13           |            |            |            | 5.25         | 6.69       |            |            |            |            |            |            |            |            |              |
|  | 45 ELBOW                                    | 0.94       | 1.91           |            |            |            | 1.63           |            |            |            | 4.31         | 4.81       |            |            |            |            |            |            |            |            |              |
|  | TEE   | 1.31       | 3.31           |            |            |            | 2.64           |            |            |            | 7.48         | 7.88       |            |            |            |            |            |            |            |            |              |
|  | COUP/RED ***                                | 0.56       | 1.00           |            |            |            | 1.00           |            |            |            | 2.00         | 2.19       |            |            |            |            |            |            |            |            |              |
|  | SOCKOLET **                                 | 0.60       | 1.30           |            |            |            | 1.04           |            |            |            | 2.00         | 2.00       |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
|  | FORGED STEEL<br>THREADED:                   | 2000       | PRESSURE CLASS |            |            |            | PRESSURE CLASS |            |            |            | 2000         | 3000       | 6000       |            |            |            |            |            |            |            |              |
|  | 90 ELBOW                                    | 1.13       | 2.27           |            |            |            | 2.18           |            |            |            | 3.50         | 7.50       |            |            |            |            |            |            |            |            |              |
|  | 45 ELBOW                                    | 1.06       | 1.99           |            |            |            | 1.74           |            |            |            | 3.00         | 5.75       |            |            |            |            |            |            |            |            |              |
|  | TEE   | 1.36       | 3.03           |            |            |            | 2.80           |            |            |            | 7.04         | 9.63       |            |            |            |            |            |            |            |            |              |
|  | COUP/RED ***                                | --         | 0.63           |            |            |            | --             |            |            |            | 2.19         | 4.38       |            |            |            |            |            |            |            |            |              |
| THREDOLET **                                   | --  | 0.62       |                |            |            | --         |                |            |            | 1.00       | 1.96         |            |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
| F<br>L<br>A<br>N<br>G<br>E<br>S                | FORGED<br>STEEL:                            | 150        | 300            | CLASS      |            |            |                | CLASS      |            |            |              | 150        | 300        | 600        | 1500       | 2500       |            |            |            |            |              |
|  | WELDING NECK                                | 2.5        | 4              | 600        |            |            |                | 600        |            |            |              | 1500       | 2500       |            |            |            |            |            |            |            |              |
|  | SLIP-ON                                     | 2          | 3              | 4          |            |            |                | 4          |            |            |              | 8.5        | 13         |            |            |            |            |            |            |            |              |
|  | THREADED                                    | 2          | 3              | 3.5        |            |            |                | 3.5        |            |            |              | 7.5        | 12         |            |            |            |            |            |            |            |              |
|  | LAP JOINT                                   | 2          | 3              | 3.5        |            |            |                | 3.5        |            |            |              | 7.5        | 12         |            |            |            |            |            |            |            |              |
|  | SOCKET                                      | 2          | 3              | 4          |            |            |                | 4          |            |            |              | 8          |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
| V<br>A<br>L<br>V<br>E<br>S                     | FORGED & CAST<br>STEEL:                     | 150        | 300            | CLASS      |            |            |                | CLASS      |            |            |              | 150        | 300        | 600        | 1500       | 2500       |            |            |            |            |              |
|  | GATE-FLGD                                   | 12.1       | 15.4           | 17.2       |            |            |                | 21.5       |            |            |              | 29.2       | 30.0       | 80         |            |            |            |            |            |            |              |
|  | GLOBE-FLGD                                  | 11.9       | 15.6           | 17         |            |            |                | 25         |            |            |              | 29.9       | 33.5       | 80         |            |            |            |            |            |            |              |
|  | CHECK-FLGD                                  | 9          | 13.7           | 16.3       |            |            |                | 20.7       |            |            |              | 27.9       | 33         | 57         |            |            |            |            |            |            |              |
|  | GATE-THRD/SW                                |            |                | 24.7       |            |            |                |            |            |            |              |            |            | 58.4       |            |            |            |            |            |            |              |
|  | GLOBE-THRD/SW                               |            |                | 26.9       |            |            |                |            |            |            |              |            |            | 59         |            |            |            |            |            |            |              |
|  | CHECK-THRD/SW                               |            |                | 15         |            |            |                |            |            |            |              |            |            | 49.1       |            |            |            |            |            |            |              |
|  | GATE PSB-SW                                 |            |                | 22         |            |            |                |            |            |            |              |            |            | 39         |            |            |            |            |            |            |              |
|  | GATE PSB-BW                                 |            |                | 21         |            |            |                |            |            |            |              |            |            | 37         |            |            |            |            |            |            |              |
|  | GLOBE PSB-SW                                |            |                | 20         |            |            |                |            |            |            |              |            |            | 45         |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
|  |   |            |                |            |            |            |                |            |            |            |              |            |            |            |            |            |            |            |            |            |              |
| I<br>N<br>S<br>U<br>L<br>A<br>T<br>I<br>O<br>N | TEMPERATURE<br>RANGE deg F                  | 100<br>199 | 200<br>299     | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699     | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>700 | 800<br>899 | 900<br>999 | 1000<br>1199 |
|  | Cal Sil. in.<br>Weight lb/ft                | 1<br>0.7   | 1<br>0.7       | 1.5<br>1.2 | 2<br>1.9   | 2<br>1.9   | 2.5<br>2.8     | 2.5<br>2.8 | 3<br>3.7   | 3<br>3.7   | 3<br>3.7     | 1<br>0.8   | 1<br>0.8   | 1.5<br>1.4 | 2<br>2.5   | 2<br>2.5   | 2.5<br>3.5 | 2.5<br>3.5 | 3<br>4.5   | 3<br>4.5   | 3<br>4.5     |
|  | H. T. C. in.<br>85% Mag in.<br>Weight lb/ft | 1<br>0.7   | 1<br>0.7       | 1.5<br>1.2 | 2<br>1.9   | 2<br>1.9   | 2.5<br>3.3     | 2.5<br>3.3 | 3<br>4.7   | 3<br>4.7   | 3<br>4.7     | 1<br>0.8   | 1<br>0.8   | 1.5<br>1.4 | 2<br>2.5   | 2<br>2.5   | 2.5<br>4.2 | 2.5<br>4.2 | 3<br>5.6   | 3<br>5.6   | 3<br>5.6     |
|  | BOLTS *                                     | 1          | 2              | 2          | 6          | 6          |                |            |            |            |              |            | 1          | 3.5        | 3.5        | 9          | 12         |            |            |            |              |

\*Weights for bolts are for one complete flange set. \*\*Weights are for reducing Sockolets and Thredolets. \*\*\*Weights for reducers are for one pipe size reduction. PSB indicates valves having pressure seal bonnets. Other weights for valves are for valves having flanged bonnets.

# TABLES W-1

# WEIGHTS OF PIPING

|  |   | NOMINAL PIPE SIZE: 2" |            |            |            |            |            |            |            |            |                | NOMINAL PIPE SIZE: 3" |            |            |            |            |            |            |            |            |              |
|--|---|-----------------------|------------|------------|------------|------------|------------|------------|------------|------------|----------------|-----------------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| F<br>I<br>T<br>T<br>I<br>N<br>G<br>S           | BUTT WELDING:<br>SCHEDULE No.<br>MFR'S WEIGHT | 40<br>STD             |            | 80<br>XS   |            | 160<br>-   |            | -XXS       |            |            |                | 40<br>STD             |            | 80<br>XS   |            | 160<br>-   |            | -XXS       |            |            |              |
|  | LR 90 ELBOW                                   | 1.60                  |            | 2.20       |            | 3.25       |            | 3.50       |            |            |                | 5.00                  |            | 6.50       |            | 8.50       |            | 11.0       |            |            |              |
|  | SR 90 ELBOW                                   | 1.00                  |            | 1.50       |            | --         |            | --         |            |            |                | 3.00                  |            | 4.25       |            | --         |            | --         |            |            |              |
|  | LR 45 ELBOW                                   | 0.81                  |            | 1.19       |            | 1.56       |            | 2.00       |            |            |                | 2.63                  |            | 3.50       |            | 4.38       |            | 5.75       |            |            |              |
|  | TEE   | 3.50                  |            | 4.00       |            | 5.00       |            | 6.25       |            |            |                | 7.00                  |            | 8.50       |            | 10.0       |            | 13.5       |            |            |              |
|  | REDUCER ***                                   | 0.90                  |            | 1.20       |            | 1.60       |            | 2.38       |            |            |                | 1.80                  |            | 2.60       |            | 3.40       |            | 5.00       |            |            |              |
|  | WELDOLET **                                   | 1.75                  |            | 1.75       |            | 2.13       |            | 2.13       |            |            |                | 4.00                  |            | 4.10       |            | 6.32       |            | 6.32       |            |            |              |
|  | FORGED STEEL<br>SOCKET WELD:                  | PRESSURE CLASS        |            |            |            |            |            |            |            |            |                | PRESSURE CLASS        |            |            |            |            |            |            |            |            |              |
|  | 90 ELBOW                                      | 3000                  |            | 6000       |            | 9000       |            |            |            |            |                | 3000                  |            | 6000       |            |            |            |            |            |            |              |
|  | 45 ELBOW                                      | 3.13                  |            | 6.66       |            | 6.69       |            |            |            |            |                | 10.9                  |            | 19.3       |            |            |            |            |            |            |              |
| TEE  | 2.71  |                       | 4.81       |            | 9.62       |            |            |            |            |            | 10.5           |                       | 14.3       |            |            |            |            |            |            |            |              |
| COUP/RED ***                                   | 4.07  |                       | 8.24       |            | 8.75       |            |            |            |            |            | 12.5           |                       | 23.5       |            |            |            |            |            |            |            |              |
| SOCKOLET **                                    | 2.00  |                       | 3.88       |            | 4.66       |            |            |            |            |            | 3.88           |                       | 6.63       |            |            |            |            |            |            |            |              |
|  | 1.60  |                       | 5.13       |            | 5.13       |            |            |            |            |            | 3.80           |                       | --         |            |            |            |            |            |            |            |              |
| FORGED STEEL<br>THREADED:                      | PRESSURE CLASS                                |                       |            |            |            |            |            |            |            |            | PRESSURE CLASS |                       |            |            |            |            |            |            |            |            |              |
| 90 ELBOW                                       | 2000  |                       | 3000       |            | 6000       |            |            |            |            |            | 2000           |                       | 3000       |            | 6000       |            |            |            |            |            |              |
| 45 ELBOW                                       | 3.14  |                       | 5.92       |            | 13.4       |            |            |            |            |            | 10.9           |                       | 14.4       |            | 39.1       |            |            |            |            |            |              |
| TEE  | 2.88  |                       | 4.93       |            | 9.50       |            |            |            |            |            | 11.3           |                       | 13.6       |            | 30.6       |            |            |            |            |            |              |
| COUP/RED ***                                   | 4.46  |                       | 7.55       |            | 18.5       |            |            |            |            |            | 12.9           |                       | 23.1       |            | 47.5       |            |            |            |            |            |              |
| THREDOLET **                                   | --  |                       | 3.13       |            | 7.75       |            |            |            |            |            | --             |                       | 6.75       |            | 13.5       |            |            |            |            |            |              |
|  | --  |                       | 1.75       |            | 5.08       |            |            |            |            |            | --             |                       | 4.35       |            | --         |            |            |            |            |            |              |
| MALL. IRON<br>THREADED:                        | PRESSURE CLASS                                |                       |            |            |            |            |            |            |            |            | PRESSURE CLASS |                       |            |            |            |            |            |            |            |            |              |
| 90 ELBOW                                       | 150   |                       | 300        |            |            |            |            |            |            |            | 150            |                       | 300        |            |            |            |            |            |            |            |              |
| 45 ELBOW                                       | 2.16  |                       | 4.00       |            |            |            |            |            |            |            | 5.37           |                       | 9.46       |            |            |            |            |            |            |            |              |
| TEE  | 1.82  |                       | 3.70       |            |            |            |            |            |            |            | 4.75           |                       | 8.54       |            |            |            |            |            |            |            |              |
| COUPLING                                       | 2.81  |                       | 5.35       |            |            |            |            |            |            |            | 7.77           |                       | 13.2       |            |            |            |            |            |            |            |              |
| REDUCER ***                                    | 1.48  |                       | 3.60       |            |            |            |            |            |            |            | 3.72           |                       | 8.00       |            |            |            |            |            |            |            |              |
|  | 1.47  |                       | 2.88       |            |            |            |            |            |            |            | 3.87           |                       | 6.60       |            |            |            |            |            |            |            |              |
| F<br>L<br>A<br>N<br>G<br>E<br>S                | FORGED<br>STEEL:                              | 150                   |            | 300        |            | 600        |            | 1500       |            | 2500       |                | 150                   |            | 300        |            | 600        |            | 1500       |            | 2500       |              |
|  | WELDING NECK                                  | 6                     |            | 8          |            | 10         |            | 24         |            | 42         |                | 11.5                  |            | 18         |            | 18         |            | 48         |            | 94         |              |
|  | SLIP-ON                                       | 5                     |            | 7          |            | 8          |            | 22         |            | --         |                | 9                     |            | 13         |            | 15         |            | --         |            | --         |              |
|  | THREADED                                      | 5                     |            | 7          |            | 8          |            | 22         |            | 38         |                | 10                    |            | 14         |            | 15         |            | 48         |            | 83         |              |
|  | LAP JOINT                                     | 5                     |            | 7          |            | 8          |            | 21         |            | 37         |                | 9                     |            | 14.5       |            | 14         |            | 38         |            | 80         |              |
|  | SOCKET  | 5                     |            | 7          |            | 9          |            | 24         |            | --         |                | 8                     |            | 13         |            | 16         |            | --         |            | --         |              |
| V<br>A<br>L<br>V<br>E<br>S                     | CAST<br>STEEL:                                | 150                   |            | 300        |            | 600        |            | 1500       |            | 2500       |                | 150                   |            | 300        |            | 600        |            | 1500       |            | 2500       |              |
|  | GATE-FLGD                                     | 46                    |            | 74         |            | 84         |            | 180        |            |            |                | 76                    |            | 108        |            | 160        |            | 370        |            |            |              |
|  | GLOBE-FLGD                                    | 47                    |            | 83         |            | 90         |            | 160        |            |            |                | 91                    |            | 135        |            | 160        |            |            |            |            |              |
|  | CHECK-FLGD                                    | 35                    |            | 60         |            | 70         |            | 155        |            |            |                | 70                    |            | 115        |            | 135        |            | 280        |            |            |              |
|  | GATE-BW                                       | 45                    |            | 49         |            | 72         |            | 130        |            |            |                | 62                    |            | 85         |            | 140        |            | 300        |            |            |              |
|  | GLOBE-BW                                      | 34                    |            | 72         |            | 78         |            | 53 SW      |            |            |                | 75                    |            | 105        |            | 130        |            |            |            |            |              |
|  | CHECK-BW                                      | 25                    |            | 47         |            | 55         |            | 47         |            |            |                | 50                    |            | 87         |            | 100        |            | 210        |            |            |              |
|  | GATE PSB-                                     |                       |            |            |            |            |            | 55 SW      |            |            |                |                       |            |            |            | 105 FLGD   |            |            |            |            |              |
|  | GATE PSB-BW                                   |                       |            |            |            |            |            |            |            |            |                |                       |            |            |            | 70         |            | 110        |            | 170        |              |
|  | GLOBE PSB-                                    |                       |            |            |            |            |            |            |            |            |                |                       |            |            |            | 155 BW     |            | 220 BW     |            | 670 BW     |              |
| I<br>N<br>S<br>U<br>L<br>A<br>T<br>I<br>O<br>N | TEMPERATURE<br>RANGE deg F                    | 100<br>199            | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199   | 100<br>199            | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 |
|  | Cal Sil. in.<br>Weight lb/ft                  | 1<br>1.0              | 1<br>1.0   | 1.5<br>1.7 | 2<br>2.5   | 2<br>2.5   | 2.5<br>3.5 | 2.5<br>3.5 | 3<br>4.2   | 3<br>4.2   | 3<br>4.2       | 1<br>1.3              | 1<br>1.3   | 1.5<br>2.1 | 2<br>3.0   | 2<br>3.0   | 2.5<br>4.1 | 3.0<br>5.2 | 3<br>5.2   | 3<br>5.2   | 3.5<br>6.7   |
|  | H. T. C. in.<br>85% Mag in.<br>Weight lb/ft   | 1<br>1.0              | 1<br>1.0   | 1.5<br>1.7 | 2<br>2.5   | 2<br>2.5   | 2.5<br>4.3 | 2.5<br>4.3 | 3<br>5.9   | 3<br>5.9   | 3<br>5.9       | 1<br>1.3              | 1<br>1.3   | 1.5<br>2.1 | 2<br>3.0   | 2<br>3.0   | 2.5<br>5.1 | 3.0<br>6.9 | 3<br>6.9   | 3<br>6.9   | 3.5<br>9.2   |
|  | BOLTS*  | 1.5                   |            | 4          |            | 4.5        |            | 12.5       |            | 21         |                | 1.5                   |            | 7.5        |            | 8          |            | 25         |            | 37         |              |

\*Weights for bolts are for one complete flange set. \*\*Weights are for reducing Socklets, Weldolets and Thredolets. \*\*\*Weights for reducers are for one pipe size reduction. PBS indicates valves having pressure seal bonnets. Other weights for valves are for valves having flanged bonnets.

# TABLES W-1

# WEIGHTS OF PIPING

NOMINAL PIPE SIZE: 4"

NOMINAL PIPE SIZE: 6"

## BUTT-WELDING FITTINGS

| SCHEDULE No.:<br>MFR'S WEIGHT: | 40<br>STD | 80<br>XS | 160<br>- | -<br>XXS | 40<br>STD | 80<br>XS | 160<br>- | -<br>XXS |
|--------------------------------|-----------|----------|----------|----------|-----------|----------|----------|----------|
| LR 90 ELBOW                    | 9.00      | 13.5     | 18.0     | 20.0     | 24.5      | 35.0     | 57.0     | 65.0     |
| SR 90 ELBOW                    | 6.25      | 8.50     | -        | -        | 18.0      | 23.0     | -        | -        |
| LR 45 ELBOW                    | 4.50      | 6.10     | 8.75     | 10.8     | 12.0      | 17.5     | 30.0     | 32.0     |
| TEE                            | 12.0      | 15.8     | 25.0     | 25.0     | 34.0      | 40.0     | 62.0     | 68.0     |
| REDUCER ***                    | 3.38      | 4.50     | 6.40     | 9.00     | 8.25      | 11.5     | 16.5     | 22.0     |
| WELDOLET **                    | 6.30      | 6.40     | 10.5     | 10.5     | 12.0      | 23.0     | 28.0     | 28.0     |

## FLANGES

| FORGED STEEL | 150  | 300  | CLASS<br>600 | 1500 | 2500 | 150  | 300 | CLASS<br>600 | 1500 | 2500 |
|--------------|------|------|--------------|------|------|------|-----|--------------|------|------|
| WELDING NECK | 16.5 | 26.5 | 37           | 69   | 146  | 26   | 45  | 73           | 164  | 378  |
| SLIP-ON      | 13   | 23.5 | 33           | -    | -    | 17   | 36  | 80           | -    | -    |
| THREADED     | 13   | 24   | 33           | 73   | 127  | 19.5 | 36  | 80           | 164  | 323  |
| LAP JOINT    | 12   | 24   | 31           | 75   | 122  | 18   | 38  | 78           | 170  | 314  |

## VALVES

| CAST STEEL    | 150 | 300 | CLASS<br>600 | 1500 | 2500 | 150 | 300 | CLASS<br>600 | 1500 | 2500 |
|---------------|-----|-----|--------------|------|------|-----|-----|--------------|------|------|
| GATE-FLGD     | 110 | 165 | 300          | 610  |      | 175 | 320 | 640          | 1410 |      |
| GLOBE-FLGD    | 143 | 220 | 320          |      |      | 250 | 390 | 640          |      |      |
| CHECK-FLGD    | 115 | 185 | 255          | 630  |      | 200 | 330 | 530          | 1360 |      |
| GATE-BW       | 95  | 120 | 270          | 520  |      | 165 | 245 | 520          | 1250 |      |
| GLOBE-BW      | 122 | 180 | 230          |      |      | 230 | 350 | 560          |      |      |
| CHECK BW      | 92  | 140 | 170          | 390  |      | 165 | 280 | 420          | 790  |      |
| GATE PSB-FLGD |     |     | 190          |      |      |     |     | 425          |      |      |
| GATE PSB-BW   |     |     | 110          | 190  | 335  |     |     | 285          | 490  | 840  |
| GLOBE PSB-BW  |     |     | 230          | 530  | 750  |     |     | 600          | 880  | 1440 |

## INSULATION

| TEMPERATURE<br>RANGE deg F                  | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 |
|---|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| Cal Sil. in.<br>Weight lb/ft                | 1<br>1.6   | 1<br>1.6   | 1.5<br>2.6 | 2<br>3.6   | 2.5<br>4.7 | 2.5<br>4.7 | 3<br>6.1   | 3.5<br>7.5 | 3.5<br>7.5 | 3.5<br>7.5   | 1<br>2.1   | 1.5<br>3.3 | 2<br>4.6   | 2<br>4.6   | 2.5<br>6.1 | 3<br>7.6   | 3<br>7.6   | 3.5<br>9.8 | 3.5<br>9.8 | 4<br>12      |
| H. T. C. in.<br>85% Mag in.<br>Weight lb/ft | 1<br>1.6   | 1<br>1.6   | 1.5<br>2.6 | 2<br>3.6   | 2.5<br>4.7 | 2.5<br>6.1 | 3<br>8.3   | 3.5<br>11  | 3.5<br>11  | 3.5<br>11    | 1<br>2.1   | 1.5<br>3.3 | 2<br>4.6   | 2<br>4.6   | 2.5<br>6.1 | 3<br>10    | 3<br>10    | 3.5<br>13  | 3.5<br>13  | 4<br>17      |

|        |   |     |      |    |    |   |      |    |    |     |
|--------|---|-----|------|----|----|---|------|----|----|-----|
| BOLTS* | 4 | 7.5 | 12.5 | 34 | 61 | 6 | 11.5 | 30 | 76 | 145 |
|--------|---|-----|------|----|----|---|------|----|----|-----|

\*Weights for bolts are for one complete flange set. \*\* Weights are for reducing Weldolets.  
 \*\*\*Weights for reducers are for one pipe size reduction. PSB indicates valves having  
 pressure seal bonnets. All other weights for valves are for valves having flanged bonnets.

# TABLES W-1

# WEIGHTS OF PIPING

NOMINAL PIPE SIZE: 8"

NOMINAL PIPE SIZE: 10"

## BUTT-WELDING FITTINGS

| SCHEDULE No.:<br>MFR'S WEIGHT: | 40<br>STD | 80<br>XS | 160<br>-       | -<br>XXS | 40<br>STD | 60<br>XS | 160<br>-       | XXS |
|--------------------------------|-----------|----------|----------------|----------|-----------|----------|----------------|-----|
| LR 90 ELBOW                    | 50        | 71       | 120            | 118      | 88        | 107      | 260            |     |
| SR 90 ELBOW                    | 34        | 47.5     | -              | -        | 58        | 70       | -              |     |
| LR 45 ELBOW                    | 23        | 35       | 62             | 60       | 43        | 53       | 130            |     |
| TEE                            | 55        | 75       | 110            | 120      | 85        | 105      | 260            |     |
| REDUCER ***                    | 13.3      | 18.8     | 31             | 36       | 22        | 29.5     | 57.5           |     |
| Weldolet **                    | 23        | 37       | (refer to Mfr) |          | 36        | 46       | (refer to Mfr) |     |

## FLANGES

| FORGED STEEL | 150 | 300 | CLASS<br>600 | 1500 | 2500 | 150 | 300 | CLASS<br>600 | 1500 | 2500 |
|--------------|-----|-----|--------------|------|------|-----|-----|--------------|------|------|
| WELDING NECK | 42  | 69  | 112          | 273  | 576  | 54  | 100 | 189          | 454  | 1068 |
| SLIP-ON      | 28  | 56  | 97           | -    | -    | 40  | 77  | 177          | -    | -    |
| THREADED     | 30  | 56  | 97           | 258  | 485  | 41  | 80  | 177          | 436  | 925  |
| LAP JOINT    | 28  | 55  | 112          | 286  | 471  | 36  | 88  | 195          | 485  | 897  |

## VALVES

| CAST STEEL    | 150 | 300 | CLASS<br>600 | 1500 | 2500 | 150 | 300  | CLASS<br>600 | 1500 | 2500 |
|---------------|-----|-----|--------------|------|------|-----|------|--------------|------|------|
| GATE-FLGD     | 310 | 500 | 1080         | 2600 |      | 455 | 760  | 1790         | 4910 |      |
| GLOBE-FLGD    | 420 | 740 | 800          |      |      | 570 | 1010 |              |      |      |
| CHECK-FLGD    | 390 | 620 | 900          | 2100 |      | 470 | 640  | 1250         |      |      |
| GATE-BW       | 260 | 410 | 940          | 1900 |      | 410 | 625  | 1580         | 3690 |      |
| GLOBE-BW      | 390 | 640 | 670          |      |      | 480 | 850  |              |      |      |
| CHECK-BW      | 350 | 510 | 740          | 1320 |      | 370 | 590  | 1030         |      |      |
| GATE PSB-FLGD |     |     | 855          |      |      |     |      | 1300         |      |      |
| GATE PSB-BW   |     |     | 615          | 900  | 1440 |     |      | 915          | 1540 | 2490 |
| GLOBE PSB-BW  |     |     | 800          | 1500 | 1700 |     |      | 1620         | 2500 | 3500 |

## INSULATION

| TEMPERATURE<br>RANGE deg F                  | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 |
|---|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| Cal Sil. in.<br>Weight lb/ft                | 1.5<br>4.1 | 1.5<br>4.1 | 2<br>5.6   | 2<br>5.6   | 2.5<br>7.9 | 3<br>9.5   | 3.5<br>12  | 4<br>14    | 4<br>14    | 4<br>14      | 1.5<br>5.2 | 1.5<br>5.2 | 2<br>7.1   | 2.5<br>8.9 | 2.5<br>8.9 | 3<br>11    | 3.5<br>13  | 4<br>16    | 4<br>16    | 4<br>16      |
| H. T. C. in.<br>85% Mag in.<br>Weight lb/ft | 1.5<br>4.1 | 1.5<br>4.1 | 2<br>5.6   | 2<br>5.6   | 2.5<br>8   | 3<br>13    | 3.5<br>16  | 4<br>20    | 4<br>20    | 4<br>20      | 1.5<br>5.2 | 1.5<br>5.2 | 2<br>7.1   | 2.5<br>8.9 | 2.5<br>8.9 | 3<br>15    | 3.5<br>19  | 4<br>23    | 4<br>23    | 4<br>23      |

| BOLTS* | 6.5 | 18 | 40 | 121 | 232 | 15 | 38 | 52 | 184 | 445 |
|--------|-----|----|----|-----|-----|----|----|----|-----|-----|
|--------|-----|----|----|-----|-----|----|----|----|-----|-----|

\*Weights for bolts are for one complete flange set. \*\*Weights are for reducing Weldolets.  
 \*\*\*Weights for reducers are for one pipe size reduction. PSB indicates valves having pressure seal bonnets. All other weights for valves are for valves having flanged bonnets.

# TABLES W-1

# WEIGHTS OF PIPING

NOMINAL PIPE SIZE: 12"

NOMINAL PIPE SIZE: 14"

## BUTT-WELDING FITTINGS

| SCHEDULE No.:<br>MFR'S WEIGHT: | -<br>STD | -<br>XS | 160<br>-       | -<br>XXS | 30<br>STD | -<br>XS | 160<br>-       | XXS |
|--------------------------------|----------|---------|----------------|----------|-----------|---------|----------------|-----|
| LR 90 ELBOW                    | 125      | 160     | 450            |          | 160       | 205     | 572            |     |
| SR 90 ELBOW                    | 80       | 104     | ---            |          | 105       | 140     | ---            |     |
| LR 45 ELBOW                    | 62       | 84      | 225            |          | 80        | 100     | 286            |     |
| TEE                            | 120      | 160     | 480            |          | 165       | 240     | ---            |     |
| REDUCER ***                    | 34       | 43.5    | 96             |          | 60        | 80      | ---            |     |
| WELDOLET **                    | 59       | 61      | (refer to Mfr) |          | 66        | 70      | (refer to Mfr) |     |

## FLANGES

| FORGED STEEL | 150 | 300 | CLASS<br>600 | 1500 | 2500 | 150 | 300 | CLASS<br>600 | 1500           |
|--------------|-----|-----|--------------|------|------|-----|-----|--------------|----------------|
| WELDING NECK | 88  | 142 | 226          | 690  | 1608 | 114 | 206 | 347          | (refer to Mfr) |
| SLIP-ON      | 61  | 113 | 215          | ---  | ---- | 83  | 159 | 259          | to Mfr)        |
| THREADED     | 65  | 110 | 215          | 667  | 1300 | 85  | 164 | 259          |                |
| LAP JOINT    | 60  | 139 | 240          | 749  | 1262 | 77  | 184 | 290          |                |

## VALVES

| CAST STEEL    | 150  | 300  | CLASS<br>600 | 1500 | 2500 | 150  | 300  | CLASS<br>600 | 1500 | 2500 |
|---------------|------|------|--------------|------|------|------|------|--------------|------|------|
| GATE-FLGD     | 650  | 1020 | 2570         | 7150 |      | 860  | 1380 | 3455         | 8580 |      |
| GLOBE-FLGD    | 1431 | 1675 |              |      |      | 1525 |      |              |      |      |
| CHECK-FLGD    | 635  | 950  | 1830         |      |      | 1200 | 1340 |              |      |      |
| GATE-BW       | 580  | 890  | 2160         | 4650 |      | 730  | 1220 | 2960         | 6420 |      |
| GLOBE-BW      | 1310 | 1455 |              |      |      | 1360 |      |              |      |      |
| CHECK-BW      | 560  | 720  | 1410         |      |      | 1010 | 1150 |              |      |      |
| GATE PSB-FLGD |      |      | 1750         |      |      |      |      |              |      |      |
| GATE PSB-BW   |      |      | 1405         | 2400 | 3850 |      |      | 1900         | 2710 | 4410 |
| GLOBE PSB-BW  |      |      | 2250         | 2780 | 5000 |      |      | 3510         |      |      |

## INSULATION

| TEMPERATURE<br>RANGE deg F                  | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 |
|---|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| Cal Sil. in.<br>Weight lb/ft                | 1.5<br>6   | 1.5<br>6   | 2<br>8     | 2.5<br>11  | 3<br>13    | 3<br>13    | 3.5<br>15  | 4<br>18    | 4<br>18    | 5<br>24      | 1.5<br>6.2 | 1.5<br>6.2 | 2<br>8.4   | 2.5<br>11  | 3<br>13    | 3<br>13    | 3.5<br>16  | 4<br>19    | 4<br>19    | 5<br>26      |
| H. T. C. in.<br>85% Mag in.<br>Weight lb/ft | 1.5<br>6   | 1.5<br>6   | 2<br>8.1   | 2.5<br>11  | 3<br>13    | 3<br>18    | 3.5<br>22  | 4<br>27    | 4<br>27    | 5<br>35      | 1.5<br>6.2 | 1.5<br>6.2 | 2<br>8.4   | 2.5<br>11  | 3<br>13    | 3<br>18    | 3.5<br>23  | 4<br>28    | 4<br>28    | 5<br>38      |

| BOLTS* | 15 | 49 | 91 | 306 | 622 | 22 | 62 | 118 |
|--------|----|----|----|-----|-----|----|----|-----|
|--------|----|----|----|-----|-----|----|----|-----|

\*Weights for bolts are for one complete flange set. \*\*Weights are for reducing Weldolets.  
 \*\*\*Weights for reducers are for one pipe size reduction. PSB indicates valves having pressure seal bonnets. All other weights for valves are for valves having flanged bonnets.

# TABLES W-1

# WEIGHTS OF PIPING

NOMINAL PIPE SIZE: 16"

NOMINAL PIPE SIZE: 18"

## BUTT-WELDING FITTINGS

| SCHEDULE No.:<br>MFR'S WEIGHT: | 30<br>STD | 40<br>XS | -<br>STD | -<br>XS |
|--------------------------------|-----------|----------|----------|---------|
| LR 90 ELBOW                    | 206       | 276      | 260      | 340     |
| SR 90 ELBOW                    | 132       | 174      | 167      | 219     |
| LR 45 ELBOW                    | 100       | 135      | 126      | 167     |
| TEE                            | 195       | 280      | 249      | 332     |
| REDUCER ***                    | 71        | 91       | 85       | 115     |
| WELDOLET **                    | 75        | 102      | 97       | 130     |

## FLANGES

| FORGED STEEL | 150 | 300 | CLASS<br>600 | 1500   | 150 | 300 | CLASS<br>600 | 1500   |
|--------------|-----|-----|--------------|--------|-----|-----|--------------|--------|
| WELDING NECK | 142 | 249 | 481          | (refer | 165 | 306 | 555          | (refer |
| SLIP-ON      | 106 | 210 | 366          | to     | 109 | 253 | 476          | to     |
| THREADED     | 93  | 220 | 366          | Mfr)   | 120 | 280 | 476          | Mfr)   |
| LAP JOINT    | 104 | 234 | 400          |        | 146 | 305 | 469          |        |

## VALVES

| CAST STEEL    | 150  | 300  | CLASS<br>600 | 1500 | 2500 | 150  | 300  | CLASS<br>600 | 1500 | 2500 |
|---------------|------|------|--------------|------|------|------|------|--------------|------|------|
| GATE-FLGD     | 1120 | 1960 | 4375         |      |      | 1400 | 2450 | 6020         |      |      |
| GLOBE-FLGD    |      |      |              |      |      |      |      |              |      |      |
| CHECK-FLGD    | 1450 | 1650 |              |      |      |      |      |              |      |      |
| GATE-BW       | 960  | 1620 | 3675         |      |      | 1250 | 2000 | 4460         |      |      |
| GLOBE-BW      |      |      |              |      |      |      |      |              |      |      |
| CHECK-BW      | 1250 | 1220 |              |      |      |      |      |              |      |      |
| GATE PSB-FLGD |      |      |              |      |      |      |      |              |      |      |
| GATE PSB-BW   |      |      | 2575         |      |      |      |      | 3400         |      |      |
| GLOBE PSB     |      |      |              |      |      |      |      |              |      |      |

## INSULATION

| TEMPERATURE<br>RANGE deg F                  | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 |
|---|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| Cal Sil. in.<br>Weight lb/ft                | 1.5<br>6.9 | 1.5<br>6.9 | 2<br>9.3   | 2.5<br>12  | 3<br>15    | 3<br>15    | 3.5<br>18  | 4<br>21    | 4<br>21    | 5<br>28      | 1.5<br>7.7 | 1.5<br>7.7 | 2<br>10    | 2.5<br>13  | 3<br>16    | 3<br>16    | 3.5<br>19  | 4<br>23    | 4<br>23    | 5<br>31      |
| H. T. C. in.<br>85% Mag in.<br>Weight lb/ft | 1.5<br>6.9 | 1.5<br>6.9 | 2<br>9.3   | 2.5<br>12  | 3<br>15    | 3<br>20    | 3.5<br>25  | 4<br>31    | 4<br>31    | 5<br>42      | 1.5<br>7.7 | 1.5<br>7.7 | 2<br>10    | 2.5<br>13  | 3<br>16    | 3<br>23    | 3.5<br>28  | 4<br>34    | 4<br>34    | 5<br>46      |

| BOLTS* | 31 | 83 | 152 | 41 | 101 | 193 |
|--------|----|----|-----|----|-----|-----|
|--------|----|----|-----|----|-----|-----|

\*Weights for bolts are for one complete flange set. \*\*Weights are for reducing Weldolets.  
 \*\*\*Weights for reducers are for one pipe size reduction. PSB indicates valves having  
 pressure seal bonnets. All other weights for valves are for valves having flanged bonnets.

# TABLES W-1

# WEIGHTS OF PIPING

NOMINAL PIPE SIZE: 20"

NOMINAL PIPE SIZE: 24"

## BUTT-WELDING FITTINGS

| SCHEDULE No.:<br>MFR'S WEIGHT: | 20<br>STD | 30<br>XS | 20<br>STD | --<br>XS |
|--------------------------------|-----------|----------|-----------|----------|
| LR 90 ELBOW                    | 320       | 420      | 460       | 600      |
| SR 90 ELBOW                    | 210       | 275      | 298       | 392      |
| LR 45 ELBOW                    | 160       | 206      | 238       | 300      |
| TEE                            | 342       | 480      | 528       | 610      |
| REDUCER ***                    | 125       | 170      | 150       | 200      |
| WELDOLET **                    | 118       | 158      | 220       | 290      |

## FLANGES

| FORGED STEEL | 150 | 300 | CLASS<br>600 | 1500   | 150 | 300 | CLASS<br>600 | 1500   |
|--------------|-----|-----|--------------|--------|-----|-----|--------------|--------|
| WELDING NECK | 197 | 369 | 690          | (refer | 268 | 579 | 977          | (refer |
| SLIP-ON      | 148 | 307 | 612          | to     | 204 | 490 | 876          | to     |
| THREADED     | 155 | 325 | 612          | Mfr)   | 210 | 490 | 876          | Mfr)   |
| LAP JOINT    | 159 | 375 | 604          |        | 195 | 530 | 866          |        |

## VALVES

| CAST STEEL    | 150  | 300  | CLASS<br>600 | 1500 | 2500 | 150  | 300  | CLASS<br>600 | 1500 | 2500 |
|---------------|------|------|--------------|------|------|------|------|--------------|------|------|
| GATE-FLGD     | 2125 | 3890 | 7015         |      |      | 3120 | 5955 | 9360         |      |      |
| GLOBE-FLGD    |      |      |              |      |      |      |      |              |      |      |
| CHECK-FLGD    |      |      |              |      |      |      |      |              |      |      |
| GATE-BW       | 1855 | 3370 | 5755         |      |      | 2500 | 4675 | 8020         |      |      |
| GLOBE-BW      |      |      |              |      |      |      |      |              |      |      |
| CHECK-BW      |      |      |              |      |      |      |      |              |      |      |
| GATE PSB-FLGD |      |      |              |      |      |      |      |              |      |      |
| GATE PSB-BW   |      |      | 5200         |      |      |      |      | 6800         |      |      |
| GLOBE PSB-BW  |      |      |              |      |      |      |      |              |      |      |

## INSULATION

| TEMPERATURE<br>RANGE deg F                  | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 | 100<br>199 | 200<br>299 | 300<br>399 | 400<br>499 | 500<br>599 | 600<br>699 | 700<br>799 | 800<br>899 | 900<br>999 | 1000<br>1199 |
|---|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| Cal Sil. in.<br>Weight lb/ft                | 1.5<br>8.5 | 1.5<br>8.5 | 2<br>12    | 2.5<br>15  | 3<br>18    | 3<br>18    | 3.5<br>21  | 4<br>25    | 4<br>25    | 5<br>34      | 1.5<br>10  | 1.5<br>10  | 2<br>13    | 2.5<br>17  | 3<br>21    | 3<br>21    | 3.5<br>25  | 4<br>29    | 4<br>29    | 5<br>39      |
| H. T. C. in.<br>85% Mag in.<br>Weight lb/ft | 1.5<br>8.5 | 1.5<br>8.5 | 2<br>12    | 2.5<br>15  | 3<br>18    | 3<br>25    | 3.5<br>31  | 4<br>37    | 4<br>37    | 5<br>50      | 1.5<br>10  | 1.5<br>10  | 2<br>13    | 2.5<br>17  | 3<br>21    | 3<br>29    | 3.5<br>36  | 4<br>43    | 4<br>43    | 5<br>58      |

| BOLTS* | 52 | 105 | 242 | 71 | 174 | 360 |
|--------|----|-----|-----|----|-----|-----|
|--------|----|-----|-----|----|-----|-----|

\*Weights for bolts are for one complete flange set. \*\*Weights are for reducing Weldolets.  
 \*\*\*Weights for reducers are for one pipe size reduction. PSB indicates valves having  
 pressure seal bonnets. All other weights for valves are for valves having flanged bonnets.

# WEIGHTS OF MATERIALS

# TABLE W-2

| MATERIAL                        |                                   | specific gravity | lb<br>in <sup>3</sup> | lb<br>ft <sup>3</sup> | lb<br>ft <sup>2</sup> -in | Kg<br>m <sup>3</sup> | lb<br>US gal | lb<br>Imp gal |
|---------------------------------|-----------------------------------|------------------|-----------------------|-----------------------|---------------------------|----------------------|--------------|---------------|
| METALS<br>&<br>ALLOYS           | Aluminum (2S)                     | 2.71             | 0.0978                | 169                   | 14.1                      | 2710                 |              |               |
|                                 | Aluminum bronze                   | 7.70             | 0.278                 | 481                   | 40.1                      | 7700                 |              |               |
|                                 | Brasses: %Cu %Zn                  |                  |                       |                       |                           |                      |              |               |
|                                 | Red brass 85 15                   | 8.75             | 0.379                 | 546                   | 45.5                      | 8750                 |              |               |
|                                 | Low brass 80 20                   | 8.67             | 0.376                 | 541                   | 45.1                      | 8670                 |              |               |
|                                 | Cartridge brass 70 30             | 8.52             | 0.369                 | 532                   | 44.3                      | 8520                 |              |               |
|                                 | Muntz metal 60 40                 | 8.39             | 0.364                 | 524                   | 43.7                      | 8390                 |              |               |
|                                 | Bronze, %Cu=80-95, %Sn=20-5       | 8.84             | 0.319                 | 552                   | 46.0                      | 8840                 |              |               |
|                                 | Copper                            | 8.91             | 0.322                 | 556                   | 46.3                      | 8900                 |              |               |
|                                 | Iron, gray-cast                   | 7.21             | 0.260                 | 450                   | 37.5                      | 7210                 |              |               |
|                                 | malleable                         | 7.34             | 0.267                 | 461                   | 38.4                      | 7380                 |              |               |
|                                 | wrought                           | 7.69             | 0.278                 | 480                   | 40.0                      | 7690                 |              |               |
|                                 | Lead                              | 11.37            | 0.411                 | 710                   | 59.2                      | 11370                |              |               |
|                                 | Monel                             | 8.83             | 0.319                 | 551                   | 45.9                      | 8830                 |              |               |
|                                 | Nickel                            | 8.87             | 0.321                 | 554                   | 46.2                      | 8870                 |              |               |
| LIQUIDS                         | Steel, carbon                     | 7.85             | 0.284                 | 490                   | 40.8                      | 7850                 |              |               |
|                                 | stainless, %Cr=18,%Ni=8           | 7.93             | 0.286                 | 495                   | 41.3                      | 7930                 |              |               |
|                                 | Fuel oil                          | 0.95             | 0.034                 | 59                    |                           |                      | 7.9          | 9.5           |
|                                 | Gasoline                          | 0.67             | 0.024                 | 42                    |                           |                      | 5.6          | 6.7           |
|                                 |                                   | thru             | thru                  | thru                  |                           |                      | thru         | thru          |
|                                 | Lube oil                          | 0.75             | 0.027                 | 47                    |                           |                      | 6.3          | 7.5           |
|                                 | Jet fuel                          | 0.90             | 0.032                 | 56                    |                           |                      | 7.5          | 9.0           |
|                                 | Water, fresh                      | 0.82             | 0.030                 | 51                    |                           |                      | 6.8          | 8.2           |
| INSULATING<br>MATERIALS         | Water, salt (seawater)            | 1.00             | 0.036                 | 62.3                  |                           |                      | 8.33         | 10.0          |
|                                 |                                   | 1.03             | 0.037                 | 64                    |                           |                      | 8.6          | 10.3          |
|                                 | Abestos                           | 2.45             | 0.0885                | 153                   | 12.8                      | 2450                 |              |               |
|                                 | Cork                              | 0.24             | 0.0087                | 15.0                  | 1.25                      | 240                  |              |               |
|                                 | Fiberglas (Owens/Corning "Kaylo") | 0.176            | 0.0064                | 11.0                  | 0.92                      | 176                  |              |               |
|                                 | Magnesia (85%)                    | 0.18             | 0.0064                | 11.0                  | 0.92                      | 176                  |              |               |
|                                 | Plastic foam                      | 0.08             | 0.0029                | 5.0                   | 0.42                      | 80                   |              |               |
|                                 |                                   | thru             | thru                  | thru                  | thru                      | thru                 |              |               |
| MATERIALS<br>OF<br>CONSTRUCTION |                                   | 0.10             | 0.0038                | 6.5                   | 0.54                      | 104                  |              |               |
|                                 | Brick, common                     | 1.92             | 0.069                 | 120                   | 10.0                      | 1920                 |              |               |
|                                 | Concrete, plain                   | 2.31             | 0.083                 | 144                   | 12.0                      | 2310                 |              |               |
|                                 | reinforced                        | 2.40             | 0.088                 | 150                   | 12.5                      | 2400                 |              |               |
|                                 | Earth, dry, loose                 | 1.22             | 0.044                 | 76                    | 6.3                       | 1220                 |              |               |
|                                 | dry, packed                       | 1.52             | 0.055                 | 95                    | 7.9                       | 1520                 |              |               |
|                                 | moist, loose                      | 1.25             | 0.045                 | 78                    | 6.5                       | 1250                 |              |               |
|                                 | moist, packed                     | 1.54             | 0.056                 | 96                    | 8.0                       | 1540                 |              |               |
|                                 | Glass                             | 2.50             | 0.090                 | 156                   | 13.0                      | 2500                 |              |               |
|                                 | Gravel, dry                       | 1.60             | 0.058                 | 100                   | 8.3                       | 1600                 |              |               |
|                                 | wet                               | 1.92             | 0.069                 | 120                   | 10.0                      | 1920                 |              |               |
|                                 | Sand, dry                         | 1.60             | 0.058                 | 100                   | 8.3                       | 1600                 |              |               |
|                                 | wet                               | 1.92             | 0.069                 | 120                   | 10.0                      | 1920                 |              |               |
|                                 | Snow, loose                       | 0.13             | 0.0046                | 8                     | 0.7                       | 130                  |              |               |

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| FRACTIONAL<br>EQUIVALENTS | 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.38 | 0.44 | 0.50 | 0.56 | 0.62 | 0.69  | 0.75 | 0.81  | 0.88 | 0.94  |
|---------------------------|------|------|------|------|------|------|------|------|------|------|-------|------|-------|------|-------|
|                           | 1/16 | 1/8  | 3/16 | 1/4  | 5/16 | 3/8  | 7/16 | 1/2  | 9/16 | 5/8  | 11/16 | 3/4  | 13/16 | 7/8  | 15/16 |

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# METRIC

The USA uses two systems of weight and measures: the United States system of English origin, and the metric system of French origin.

The English or Imperial system was a customary system with origins in Babylonian, Egyptian, Greek, Roman, Anglo-Saxon, French (Norman) and other civilizations and cultures. The English system evolved over centuries from simple measures and practices, eventually attaining precision through legislation and standardization. Although some standardization resulted from reform (sometimes a royal decree), the overwhelming pressure came from expansion in industry and commerce.

Imperial Rome established a system of weights and measures used from England to Asia. But, with the decline of the Roman Empire, what was once an almost universal system degenerated into local customary systems in continental Europe and England.

By the 17th and 18th centuries, through colonization and dominance in commerce, the English system had developed to a point where it was in use in many parts of the world, including the American colonies. The French, however, decided to abandon the confusion of European customary units (which varied not only from country to country, but from province to province and sometimes, from city to city), and to create an entirely new system to rationalize weights and measures - the Metric System.

The metric system was the result of years of scientific investigation and recommendations for reform. It was adopted in the late 18th century by the post-revolutionary government of France and, subsequently, by other nations. The standardized units and decimal base were particularly well suited for science and engineering.

By the middle of the 20th century, principal manufacturing countries not using the metric system were Britain, the British Commonwealth countries and the United States. Although in 1866 the U.S. Congress legalized the metric system for use throughout the United States and, in 1975 passed the Metric Conversion Act, the United States is the only major industrial nation today, neither to have adopted nor mandated use of the metric system as its primary system of measurement.

In 1960, at the General Conference of Weights and Measures (Conference Generale des Poids et Mesures [CGPM]), the modern version of the metric system was designated the International System of Units (Le Systeme International d'Unites), and endorsed by the International Organization for Standardization (ISO) - a federation of national standardization bodies representing most countries of the world. The international symbol for this system is SI.

SI, now the primary world system of units of measurement, is a rationalized selection of units from the metric system with which ISO seeks to establish international standards, especially those for universal interchangeability of components. SI simplifies measurement by logically coordinating unique units for length, mass, temperature, time, etc., in a decimal system in which the magnitude of a unit is changed by moving the decimal point (or, for example, by using a prefix such as 'milli' with meter for the factor 0.001).

The customary system is more complicated as it uses three types of subdivision: duodecimal (twelfths), decimal (tenths), and binary (halves), and requires conversion, for example, between different units of length (such as inches, feet and yards), or of mass (such as ounces, pounds and tons).

Changing from customary units to SI units is straightforward, but changing from traditional metric units to SI units is more difficult in countries already using the metric system. Because of this difficulty, although not in keeping with the goals of ISO, a limited number of traditional metric units are temporarily being used with SI; one such unit is bar, the unit for pressure, referred to below under 'Flange Classes and Pressure Numbers'.

Without a legislative mandate, full implementation of SI in the United States is unlikely; however, technical and economic requirements of American companies operating internationally are encouraging voluntary transition; for example, manufacturers of equipment and components are now presenting dimensional and other data in SI units (and temporary metric units in use with SI) in addition to U.S. customary units.

## NOMINAL LINES SIZES

Sizes of pipe, fittings, flanges, and valves are given in nominal diameters - in inch units as NPS (Nominal Pipe Size) and in metric units as DN (Diametre Nomiale [Nominal Diameter]). The following table gives equivalent diameters in nominal inch units and nominal millimeter units:

| CUSTOMARY<br>NPS (inch) | METRIC<br>DN (mm) | CUSTOMARY<br>NPS (inch) | METRIC<br>DN (mm) | CUSTOMARY<br>NPS (inch) | METRIC<br>DN (mm) |
|-------------------------|-------------------|-------------------------|-------------------|-------------------------|-------------------|
| 1/8                     | 6                 | 6                       | 150               | 30                      | 750               |
| 1/4                     | 8                 | 8                       | 200               | 32                      | 800               |
| 3/8                     | 10                | 10                      | 250               | 36                      | 900               |
| 1/2                     | 15                | 12                      | 300               | 40                      | 1000              |
| 3/4                     | 20                | 14                      | 350               | 42                      | 1100              |
| 1                       | 25                | 16                      | 400               | 48                      | 1200              |
| 1 1/4*                  | 32                | 18                      | 450               | 54                      | 1400              |
| 1 1/2                   | 40                | 20                      | 500               | 60                      | 1500              |
| 2                       | 50                | 22                      | 550               | 64                      | 1600              |
| 2 1/2*                  | 65                | 24                      | 600               | 72                      | 1800              |
| 3                       | 80                | 26                      | 650               | 80                      | 2000              |
| 4                       | 100               | 28                      | 700               | 88                      | 2200              |

\* These sizes may be used in special applications; they are not normally used in new industrial construction.

## FLANGE CLASSES and PRESSURE NUMBERS

Earlier classifications of flanges for steel pipe (and flanged fittings): 150-lb, 300-lb, 400-lb, 600-lb, etc., referred to 'Primary Service Pressure Ratings in pounds (pounds-force) per square-inch'. (Flanges, however, are suitable for service over a range of pressure, with actual pressures depending on operating temperatures, and materials of construction.) These classifications have been supplanted by pressure rating class designations: Class 150, Class 300, etc., in which each class identifies a group of flanges conforming to established dimensions, for a range of pipe sizes.

Standards publish 'Pressure-Temperature Ratings' for each class of flange. These ratings are maximum allowable non-shock (gage), working (or service) pressures over a range of temperature for different materials of construction, including bolts and gaskets.

In addition to class designations, flange tables in this section of the 'PIPING GUIDE' also show 'PN' designations according to ANSI B16.5-1981 (until re-issued 1988), and MSS-SP-86-1981 (re-issued 1987), which states "...the recommendation for metric pressure designations is the use of the prefix PN, which may be thought of as 'Pressure Number'."

Pressure Numbers (PN), similar to class designations, identify groups of flanges conforming to established dimensions, and for each class of flange express the pressure rating within the temperature range -20 to +100F (refer to Table F-9), as a nominal bar\* value.

Class and corresponding PN designations are shown in the following table:

| CLASS | 150 | 300 | 400 | 600 | 900 | 1500 | 2500 |
|-------|-----|-----|-----|-----|-----|------|------|
| PN    | 20  | 50  | 68  | 100 | 150 | 250  | 420  |

[\* Bar is not an SI unit; pascal (Pa) is the SI unit for pressure (and stress). The pascal is a small unit. For stating process or service pressure it is used with a prefix such as kPa for kilopascal (1000 pascals), or MPa for megapascal (1 000 000 pascals), although megapascal is more suitable for the greater values of stress. Bar, equal to 100 000 pascals, is a traditional metric unit in widespread use internationally in industry and technology. Until it is displaced, bar is in temporary use with SI units. (Temporary units are specific, widely used, traditional metric units whose use in future work is discouraged.)]

Contemporary references and suppliers' literature refer to bar values and PN designations. Flange tables in this section of the 'PIPING GUIDE' include PN references for information only.

In the following pages, selected data from PT II of the 'PIPING GUIDE' are presented in SI units. For identification, these tables and charts are given the suffix 'M'.

# ARRANGING LINES / SPACING IN PIPEWAYS

DIMENSIONS IN  
MILLIMETERS

## TABLES A-1M

TABLES GIVE THE MINIMUM SPACING. INCREASE DIMENSIONS:

- 1) FOR INSULATION
- 2) IF THERMAL MOVEMENT WOULD REDUCE CLEARANCE

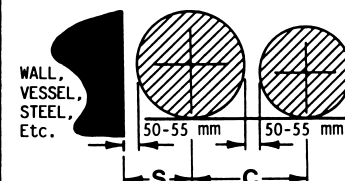
### DIMENSION - 'C'

### SURFACE-TO-CENTER OF PIPE DIMENSION

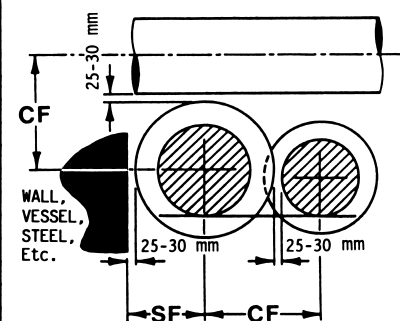
| LINES<br>WITHOUT<br>FLANGES | NOMINAL DIAMETER (DN) |     |     |     |     |     |     |     |     |     |     |     |
|-----------------------------|-----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                             | 50                    | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
| D<br>N                      | 50                    | 115 | 125 | 140 | 165 | 190 | 220 | 245 | 260 | 285 | 310 | 335 |
|                             | 80                    | 125 | 140 | 155 | 180 | 205 | 235 | 260 | 275 | 300 | 325 | 350 |
| 100                         | 140                   | 155 | 165 | 195 | 220 | 245 | 270 | 285 | 315 | 340 | 365 | 415 |
|                             | 150                   | 165 | 180 | 195 | 220 | 245 | 275 | 300 | 315 | 340 | 365 | 390 |
| 200                         | 190                   | 205 | 220 | 245 | 270 | 300 | 325 | 340 | 365 | 390 | 415 | 465 |
|                             | 250                   | 220 | 235 | 245 | 275 | 300 | 325 | 350 | 365 | 390 | 420 | 445 |
| 300                         | 245                   | 260 | 270 | 300 | 325 | 350 | 375 | 390 | 420 | 445 | 470 | 520 |
|                             | 350                   | 260 | 275 | 285 | 315 | 340 | 365 | 390 | 410 | 435 | 460 | 485 |
| 400                         | 285                   | 300 | 315 | 340 | 365 | 390 | 420 | 435 | 460 | 485 | 510 | 560 |
|                             | 450                   | 310 | 325 | 340 | 365 | 390 | 420 | 445 | 460 | 485 | 510 | 535 |
| 500                         | 335                   | 350 | 365 | 390 | 415 | 445 | 470 | 485 | 510 | 535 | 560 | 610 |
|                             | 600                   | 385 | 400 | 415 | 440 | 465 | 495 | 520 | 535 | 560 | 585 | 610 |

|     | 'S' | 'SF'               |                  |     |
|-----|-----|--------------------|------------------|-----|
|     |     | WITHOUT<br>FLANGES | FLANGE<br>CLASS: |     |
|     |     |                    | 150              | 300 |
| 50  | 85  | 105                | 110              | 110 |
| 80  | 95  | 125                | 130              | 130 |
| 100 | 110 | 140                | 155              | 165 |
| 150 | 135 | 165                | 185              | 205 |
| 200 | 160 | 200                | 220              | 235 |
| 250 | 190 | 230                | 250              | 280 |
| 300 | 215 | 270                | 290              | 305 |
| 350 | 230 | 295                | 320              | 330 |
| 400 | 255 | 325                | 350              | 370 |
| 450 | 280 | 345                | 385              | 400 |
| 500 | 305 | 375                | 415              | 435 |
| 600 | 355 | 435                | 485              | 495 |

### PIPE WITHOUT FLANGES



### PIPE WITH FLANGES



### LINES WITH FLANGES - DIMENSION 'CF'

#### CLASS 150 & CLASS 150 FLANGES

|     | 150 | NOMINAL DIAMETER (DN) OF FLANGED PIPE |     |     |     |     |     |     |     |     |     |     |     |
|-----|-----|---------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|     |     | 50                                    | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
| DN  | 50  | 135                                   | 155 | 170 | 200 | 230 | 260 | 300 | 325 | 355 | 375 | 405 | 465 |
|     | 80  | 155                                   | 170 | 185 | 210 | 245 | 275 | 315 | 340 | 370 | 390 | 420 | 480 |
| 100 | 170 | 185                                   | 200 | 225 | 255 | 290 | 325 | 350 | 385 | 405 | 435 | 490 |     |
|     | 150 | 200                                   | 210 | 225 | 250 | 285 | 315 | 355 | 380 | 410 | 430 | 460 | 520 |
| 200 | 230 | 245                                   | 255 | 285 | 310 | 340 | 380 | 405 | 435 | 455 | 485 | 545 |     |
|     | 250 | 260                                   | 275 | 290 | 315 | 340 | 370 | 405 | 430 | 465 | 480 | 515 | 570 |
| 300 | 300 | 315                                   | 325 | 355 | 380 | 405 | 430 | 455 | 490 | 505 | 540 | 595 |     |
|     | 350 | 325                                   | 340 | 350 | 380 | 405 | 430 | 455 | 470 | 505 | 525 | 555 | 610 |
| 400 | 355 | 370                                   | 385 | 410 | 435 | 465 | 490 | 505 | 530 | 555 | 580 | 640 |     |
|     | 450 | 375                                   | 390 | 405 | 430 | 455 | 480 | 505 | 525 | 555 | 575 | 605 | 665 |
| 500 | 405 | 420                                   | 435 | 460 | 485 | 515 | 540 | 555 | 580 | 605 | 630 | 690 |     |
|     | 600 | 465                                   | 480 | 490 | 520 | 545 | 570 | 595 | 610 | 640 | 665 | 690 | 740 |

#### CLASS 300 & CLASS 300 FLANGES

|     | 300 | NOMINAL DIAMETER (DN) OF FLANGED PIPE |     |     |     |     |     |     |     |     |     |     |     |
|-----|-----|---------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|     |     | 50                                    | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
| DN  | 50  | 140                                   | 165 | 185 | 215 | 250 | 280 | 320 | 350 | 380 | 415 | 445 | 515 |
|     | 80  | 165                                   | 175 | 200 | 230 | 265 | 295 | 335 | 365 | 395 | 430 | 460 | 530 |
| 100 | 185 | 200                                   | 210 | 245 | 275 | 305 | 345 | 375 | 410 | 440 | 470 | 540 |     |
|     | 150 | 215                                   | 230 | 245 | 270 | 305 | 335 | 370 | 405 | 435 | 470 | 500 | 570 |
| 200 | 250 | 265                                   | 275 | 305 | 330 | 360 | 400 | 430 | 460 | 495 | 525 | 595 |     |
|     | 250 | 280                                   | 295 | 305 | 335 | 360 | 385 | 425 | 455 | 490 | 520 | 550 | 620 |
| 300 | 320 | 335                                   | 345 | 370 | 400 | 425 | 450 | 480 | 515 | 545 | 575 | 645 |     |
|     | 350 | 350                                   | 365 | 375 | 405 | 430 | 455 | 480 | 500 | 530 | 560 | 595 | 665 |
| 400 | 380 | 395                                   | 410 | 435 | 460 | 490 | 515 | 530 | 555 | 585 | 620 | 690 |     |
|     | 450 | 415                                   | 430 | 440 | 470 | 495 | 520 | 545 | 560 | 585 | 610 | 645 | 715 |
| 500 | 445 | 460                                   | 470 | 500 | 525 | 550 | 575 | 595 | 620 | 645 | 670 | 740 |     |
|     | 600 | 515                                   | 530 | 540 | 570 | 595 | 620 | 645 | 665 | 690 | 715 | 740 | 790 |

### INSULATION

DIMENSIONS IN THESE TABLES ARE SPACINGS FOR BARE PIPE. FOR INSULATED LINES, ADD THE THICKNESS OF INSULATION AND COVERING TO THESE FIGURES

### CLASS 150 & CLASS 300 FLANGES

| 300 |     | NOMINAL DIAMETER (DN) OF FLANGED PIPE |     |     |     |     |     |     |     |     |     |     |     |
|-----|-----|---------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 150 |     | 50                                    | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
| DN  | 50  | 140                                   | 165 | 185 | 215 | 250 | 280 | 320 | 350 | 380 | 415 | 445 | 515 |
|     | 80  | 155                                   | 175 | 200 | 230 | 265 | 295 | 335 | 365 | 395 | 430 | 460 | 530 |
| O F | 100 | 170                                   | 190 | 210 | 245 | 275 | 305 | 345 | 375 | 410 | 440 | 470 | 540 |
|     | 150 | 200                                   | 215 | 240 | 270 | 305 | 335 | 370 | 405 | 435 | 470 | 500 | 570 |
| F L | 200 | 230                                   | 245 | 265 | 295 | 330 | 360 | 400 | 430 | 460 | 495 | 525 | 595 |
|     | 250 | 260                                   | 275 | 290 | 325 | 355 | 385 | 425 | 455 | 490 | 520 | 550 | 620 |
| A N | 300 | 300                                   | 315 | 325 | 355 | 380 | 410 | 450 | 480 | 515 | 545 | 575 | 645 |
|     | 350 | 325                                   | 340 | 350 | 380 | 405 | 430 | 465 | 500 | 530 | 560 | 595 | 665 |
| G D | 400 | 355                                   | 370 | 385 | 410 | 435 | 465 | 490 | 525 | 555 | 585 | 620 | 690 |
|     | 450 | 375                                   | 390 | 405 | 430 | 455 | 480 | 515 | 550 | 580 | 610 | 645 | 715 |
| P I | 500 | 405                                   | 420 | 435 | 460 | 485 | 515 | 540 | 575 | 605 | 640 | 670 | 740 |
|     | 600 | 465                                   | 480 | 490 | 520 | 545 | 570 | 595 | 625 | 655 | 690 | 720 | 790 |

### CLASS 300 & CLASS 600 FLANGES

| 600 |     | NOMINAL DIAMETER (DN) OF FLANGED PIPE |     |     |     |     |     |     |     |     |     |     |     |
|-----|-----|---------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 300 |     | 50                                    | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
| DN  | 50  | 140                                   | 165 | 195 | 235 | 270 | 310 | 340 | 360 | 400 | 430 | 465 | 530 |
|     | 80  | 165                                   | 175 | 210 | 250 | 280 | 325 | 350 | 375 | 415 | 445 | 480 | 540 |
| O F | 100 | 185                                   | 200 | 220 | 265 | 295 | 340 | 365 | 385 | 430 | 455 | 490 | 555 |
|     | 150 | 215                                   | 230 | 250 | 290 | 320 | 365 | 390 | 415 | 455 | 485 | 520 | 580 |
| F L | 200 | 250                                   | 265 | 275 | 315 | 345 | 390 | 415 | 440 | 480 | 510 | 545 | 605 |
|     | 250 | 280                                   | 295 | 305 | 340 | 375 | 420 | 445 | 465 | 505 | 535 | 570 | 635 |
| A N | 300 | 320                                   | 335 | 345 | 370 | 400 | 445 | 470 | 490 | 535 | 560 | 595 | 660 |
|     | 350 | 350                                   | 365 | 375 | 405 | 430 | 460 | 485 | 505 | 550 | 575 | 610 | 675 |
| G D | 400 | 380                                   | 395 | 410 | 435 | 460 | 490 | 515 | 535 | 575 | 605 | 640 | 700 |
|     | 450 | 415                                   | 430 | 440 | 470 | 495 | 520 | 545 | 560 | 600 | 630 | 665 | 725 |
| P I | 500 | 445                                   | 460 | 470 | 500 | 525 | 550 | 575 | 595 | 625 | 655 | 690 | 750 |
|     | 600 | 515                                   | 530 | 540 | 570 | 595 | 620 | 645 | 665 | 690 | 715 | 740 | 805 |

### CLASS 150 & CLASS 600 FLANGES

| 600 |     | NOMINAL DIAMETER (DN) OF FLANGED PIPE |     |     |     |     |     |     |     |     |     |     |     |
|-----|-----|---------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 150 |     | 50                                    | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
| DN  | 50  | 140                                   | 165 | 195 | 235 | 270 | 310 | 340 | 360 | 400 | 430 | 465 | 530 |
|     | 80  | 155                                   | 175 | 210 | 250 | 280 | 325 | 350 | 375 | 415 | 445 | 480 | 540 |
| O F | 100 | 170                                   | 190 | 220 | 265 | 295 | 340 | 365 | 385 | 430 | 455 | 490 | 555 |
|     | 150 | 200                                   | 215 | 250 | 290 | 320 | 365 | 390 | 415 | 455 | 485 | 520 | 580 |
| F L | 200 | 230                                   | 245 | 275 | 315 | 345 | 390 | 415 | 440 | 480 | 510 | 545 | 605 |
|     | 250 | 260                                   | 275 | 300 | 340 | 375 | 420 | 445 | 465 | 505 | 535 | 570 | 635 |
| A N | 300 | 300                                   | 315 | 325 | 370 | 400 | 445 | 470 | 490 | 535 | 560 | 595 | 660 |
|     | 350 | 325                                   | 340 | 350 | 385 | 415 | 460 | 485 | 505 | 550 | 575 | 610 | 675 |
| G D | 400 | 355                                   | 370 | 385 | 410 | 440 | 485 | 510 | 535 | 575 | 605 | 640 | 700 |
|     | 450 | 375                                   | 390 | 405 | 435 | 465 | 510 | 535 | 560 | 600 | 630 | 665 | 725 |
| P I | 500 | 405                                   | 420 | 435 | 460 | 490 | 535 | 560 | 585 | 625 | 655 | 690 | 750 |
|     | 600 | 465                                   | 480 | 490 | 520 | 545 | 585 | 610 | 635 | 675 | 705 | 740 | 805 |

### CLASS 600 & CLASS 600 FLANGES

| 600 |     | NOMINAL DIAMETER (DN) OF FLANGED PIPE |     |     |     |     |     |     |     |     |     |     |     |
|-----|-----|---------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 600 |     | 50                                    | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
| DN  | 50  | 140                                   | 165 | 195 | 235 | 270 | 310 | 340 | 360 | 400 | 430 | 465 | 530 |
|     | 80  | 165                                   | 175 | 210 | 250 | 280 | 325 | 350 | 375 | 415 | 445 | 480 | 540 |
| O F | 100 | 195                                   | 210 | 220 | 265 | 295 | 340 | 365 | 385 | 430 | 455 | 490 | 555 |
|     | 150 | 235                                   | 250 | 265 | 290 | 320 | 365 | 390 | 415 | 455 | 485 | 520 | 580 |
| F L | 200 | 270                                   | 280 | 295 | 320 | 345 | 390 | 415 | 440 | 480 | 510 | 545 | 605 |
|     | 250 | 310                                   | 325 | 340 | 365 | 390 | 420 | 445 | 465 | 505 | 535 | 570 | 635 |
| A N | 300 | 340                                   | 350 | 365 | 390 | 415 | 445 | 470 | 490 | 535 | 560 | 595 | 660 |
|     | 350 | 360                                   | 375 | 385 | 415 | 440 | 465 | 490 | 505 | 550 | 575 | 610 | 675 |
| G D | 400 | 400                                   | 415 | 430 | 455 | 480 | 505 | 535 | 550 | 575 | 605 | 640 | 700 |
|     | 450 | 430                                   | 445 | 455 | 485 | 510 | 535 | 560 | 575 | 605 | 630 | 665 | 725 |
| P I | 500 | 465                                   | 480 | 490 | 520 | 545 | 570 | 595 | 610 | 640 | 665 | 690 | 750 |
|     | 600 | 530                                   | 540 | 555 | 580 | 605 | 635 | 660 | 675 | 700 | 725 | 750 | 805 |

### PIPEWAY WIDTH

When the order of lines, line sizes, flange classes (for lines with flanges), and insulation thicknesses for insulated lines have been decided, determine pipeway width from Tables A-1M, A-2M and A-3M, adding 25% so that the final design includes 20% (distributed) space for future piping. Additional space will usually be required for electrical and instrument trays/raceways.

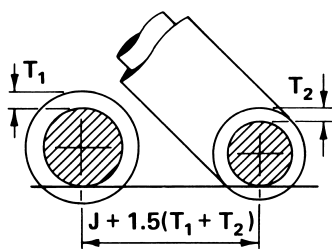
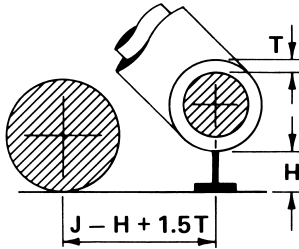
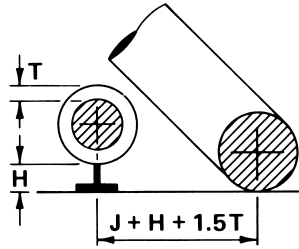
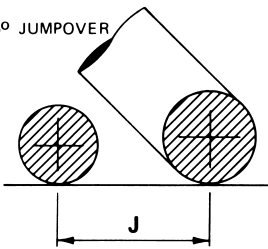
For a **tentative** estimate of the pipeway width required for a selection of lines without flanges, of nominal sizes in the range DN 50 thru DN 200, either of the following factors may be used - the first is preferable:

- (1) If all pipe sizes are known, add their nominal sizes in millimeters together and multiply by 4.1 to estimate the width in millimeters
- (2) If only the number of lines is known, multiply number of lines by 436 to estimate the width in millimeters

Either factor gives a pipeway width which includes insulation for 25% of lines, allows 20% of the width for the addition and re-sizing of lines, and allocates a further 20% of the width for future piping.

## 45° JUMPOVERS

45° JUMPOVER

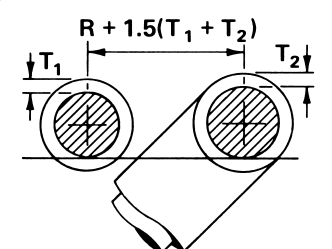
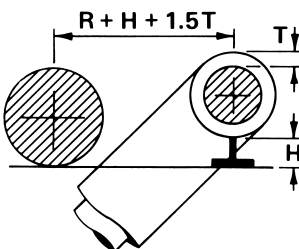
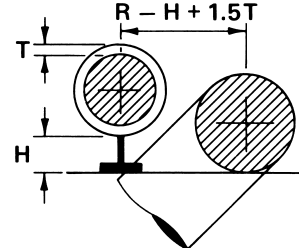
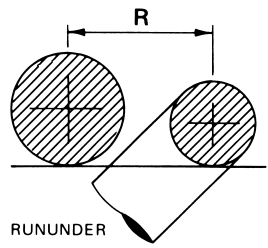


BASIC SPACING 'J'

| DN   |     | JUMPOVER LINE |     |     |     |     |     |     |     |     |     |     |     |
|--|-----|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|  |     | 50            | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
| A<br>D<br>J<br>A<br>C<br>E<br>N<br>T<br><br>L<br>I<br>N<br>E | 50  | 160           | 165 | 170 | 180 | 190 | 205 | 215 | 220 | 230 | 240 | 250 | 270 |
|  | 80  | 195           | 200 | 205 | 215 | 225 | 235 | 250 | 255 | 265 | 275 | 285 | 305 |
|  | 100 | 225           | 230 | 235 | 245 | 255 | 270 | 280 | 285 | 295 | 305 | 315 | 335 |
|  | 150 | 290           | 295 | 300 | 310 | 320 | 335 | 345 | 350 | 360 | 370 | 380 | 405 |
|  | 200 | 350           | 355 | 360 | 375 | 385 | 395 | 405 | 410 | 420 | 430 | 445 | 465 |
|  | 250 | 415           | 420 | 425 | 440 | 450 | 460 | 470 | 475 | 485 | 495 | 510 | 530 |
|  | 300 | 475           | 485 | 490 | 500 | 510 | 520 | 530 | 540 | 550 | 560 | 570 | 590 |
|  | 350 | 515           | 520 | 525 | 535 | 550 | 560 | 570 | 575 | 585 | 595 | 610 | 630 |
|  | 400 | 575           | 580 | 585 | 600 | 610 | 620 | 630 | 635 | 650 | 660 | 670 | 690 |
|  | 450 | 640           | 645 | 650 | 660 | 670 | 680 | 690 | 700 | 710 | 720 | 730 | 750 |
| 500  | 700 | 705           | 710 | 720 | 730 | 745 | 755 | 760 | 770 | 780 | 790 | 820 |     |
| 600  | 820 | 825           | 835 | 845 | 855 | 865 | 875 | 885 | 895 | 905 | 915 | 935 |     |

## 45° RUNUNDERS

45° RUNUNDER



BASIC SPACING 'R'

| DN   |     | RUNUNDER LINE |     |     |     |     |     |     |     |     |     |     |     |
|--|-----|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|  |     | 50            | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
| A<br>D<br>J<br>A<br>C<br>E<br>N<br>T<br><br>L<br>I<br>N<br>E | 50  | 160           | 195 | 225 | 290 | 350 | 415 | 475 | 515 | 575 | 640 | 700 | 820 |
|  | 80  | 165           | 200 | 230 | 295 | 355 | 420 | 485 | 520 | 580 | 645 | 705 | 825 |
|  | 100 | 170           | 205 | 235 | 300 | 360 | 425 | 490 | 525 | 585 | 650 | 710 | 835 |
|  | 150 | 180           | 215 | 245 | 310 | 375 | 440 | 500 | 535 | 600 | 660 | 720 | 845 |
|  | 200 | 190           | 225 | 255 | 320 | 385 | 450 | 510 | 550 | 610 | 670 | 730 | 855 |
|  | 250 | 205           | 235 | 270 | 335 | 395 | 460 | 520 | 560 | 620 | 680 | 745 | 865 |
|  | 300 | 215           | 250 | 280 | 345 | 405 | 470 | 530 | 570 | 630 | 690 | 755 | 875 |
|  | 350 | 220           | 255 | 285 | 350 | 410 | 475 | 540 | 575 | 635 | 700 | 760 | 885 |
|  | 400 | 230           | 265 | 295 | 360 | 420 | 485 | 550 | 585 | 650 | 710 | 770 | 895 |
|  | 450 | 240           | 275 | 305 | 370 | 430 | 495 | 560 | 595 | 660 | 720 | 780 | 905 |
| 500  | 250 | 285           | 315 | 380 | 445 | 510 | 570 | 610 | 670 | 730 | 790 | 915 |     |
| 600  | 270 | 305           | 335 | 405 | 465 | 530 | 590 | 630 | 690 | 750 | 820 | 935 |     |

### NOTES FOR TABLES A-2M & A-3M

- (1) SPACING SHOWN IN THE DIAGRAMS ALLOWS A MINIMUM CLEARANCE OF 50mm. COMPARE BASIC SPACING 'J' or 'R' WITH APPROPRIATE 'C' or 'CF' SPACING IN TABLE A-1M AND USE THE LARGER DIMENSION
- (2) 'H' IS THE EFFECTIVE SHOE HEIGHT AND 'T' IS THE THICKNESS OF INSULATION (WITH COVERING)
- (3) FOR SIMPLICITY, THE VALUE 1.5 HAS BEEN SUBSTITUTED FOR THE COEFFICIENT  $1/\sin 45$  (1.414....)

CLASS

600

## BUTT-WELDED PIPING DIMENSIONS

TABLE D-1M

DIMENSIONS IN THIS TABLE INCLUDE 6.4 mm RAISED FACE ON FLANGES

## NOMINAL DIAMETER (DN)

50

80

100

150

200

250

300

350

400

450

500

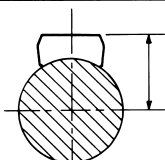
600

## FITTINGS

## STRAIGHT TEE

TABLE D-6M FOR  
REDUCING TEES

## WELDOLET

STANDARD AND  
EXTRA-STRONG

BRANCH DIAMETER

50

80

100

## REDUCERS

CONCENTRIC  
& ECCENTRIC

## 90° LR ELLS

REGULAR &  
REDUCING

## 90° SR ELL

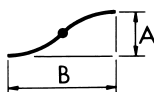


## 45° ELL (LR)



## OFFSET

(TWO 45° ELLS )

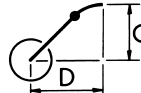


A

B

## ROLLED- ELL

(45° ELL + 90° LR ELL)



C

D

## 90° LR ELL

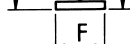
+ WELDING-NECK



E

F

## RAISED-FACE FLANGE



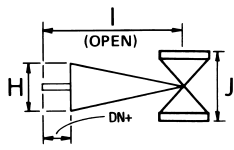
G

## VALVES

## PLUG

VENTURI PATTERN: DN 50-600  
REGULAR PATTERN: DN 50-400

## GATE

DIMENSIONS ALSO  
APPLY TO GATE  
VALVES WITH BUTT-  
WELDING ENDS

H

I

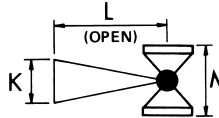
J

## BALL

LONG PATTERN:



## GLOBE

DIMENSIONS ALSO  
APPLY TO GLOBE  
VALVES WITH BUTT-  
WELDING ENDS

K

L

M

## CHECK

SWING: DN 50-600  
TILTING DISC: DN 50-600  
LIFT: DN 50-300FLANGED  
& BUTT-  
WELDING

|                               |                               |                               |                               |                               |                               |                               |                               |                               |                                |                                |                                |
|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|--------------------------------|--------------------------------|
| 64                            | 86                            | 105                           | 143                           | 178                           | 216                           | 254                           | 279                           | 305                           | 343                            | 381                            | 432                            |
| 68                            | 83                            | 95                            | 122                           | 148                           | 175                           | 200                           | 216                           | 241                           | 267                            | 292                            | 343                            |
| -                             | 89                            | 102                           | 129                           | 154                           | 181                           | 206                           | 222                           | 248                           | 273                            | 298                            | 349                            |
| -                             | -                             | 108                           | 135                           | 160                           | 187                           | 213                           | 229                           | 254                           | 279                            | 305                            | 356                            |
| Swage-<br>Table<br>D-4M       | 89                            | 102                           | 140                           | 152                           | 178                           | 203                           | 330                           | 356                           | 381                            | 508                            | 508                            |
| 76                            | 114                           | 152                           | 229                           | 305                           | 381                           | 457                           | 533                           | 610                           | 686                            | 762                            | 914                            |
| 51                            | 76                            | 102                           | 152                           | 203                           | 254                           | 305                           | 356                           | 406                           | 457                            | 508                            | 610                            |
| 35                            | 51                            | 64                            | 95                            | 127                           | 159                           | 190                           | 222                           | 254                           | 286                            | 318                            | 381                            |
| 49                            | 72                            | 90                            | 135                           | 180                           | 225                           | 269                           | 314                           | 359                           | 404                            | 449                            | 539                            |
| 119                           | 173                           | 217                           | 325                           | 434                           | 542                           | 650                           | 759                           | 867                           | 976                            | 1084                           | 1301                           |
| 79                            | 117                           | 153                           | 229                           | 305                           | 382                           | 458                           | 534                           | 611                           | 687                            | 763                            | 916                            |
| 114                           | 168                           | 216                           | 324                           | 432                           | 540                           | 648                           | 757                           | 865                           | 973                            | 1081                           | 1297                           |
| 156                           | 203                           | 260                           | 352                           | 444                           | 540                           | 619                           | 705                           | 794                           | 876                            | 959                            | 1124                           |
| 165                           | 210                           | 273                           | 356                           | 419                           | 508                           | 559                           | 603                           | 686                           | 743                            | 813                            | 940                            |
| 79                            | 89                            | 108                           | 124                           | 140                           | 159                           | 162                           | 171                           | 184                           | 191                            | 197                            | 210                            |
| <sup>R</sup> 292 <sup>V</sup> | <sup>R</sup> 356 <sup>V</sup> | <sup>R</sup> 432 <sup>V</sup> | <sup>R</sup> 559 <sup>V</sup> | <sup>R</sup> 660 <sup>V</sup> | <sup>R</sup> 787 <sup>V</sup> | <sup>R</sup> 838 <sup>V</sup> | <sup>R</sup> 889 <sup>V</sup> | <sup>R</sup> 991 <sup>V</sup> | <sup>V</sup> 1092 <sup>V</sup> | <sup>V</sup> 1194 <sup>V</sup> | <sup>V</sup> 1397 <sup>V</sup> |
| 229                           | 305                           | 406                           | 559                           | 610                           | 711                           | 762                           | 914                           | 965                           | 965                            | 1067                           | 1067                           |
| 533                           | 660                           | 838                           | 1194                          | 1346                          | 1676                          | 1854                          | 2057                          | 2362                          | 2515                           | 2718                           | 3200                           |
| 292                           | 356                           | 432                           | 559                           | 660                           | 787                           | 838                           | 889                           | 991                           | 1092                           | 1194                           | 1397                           |
| 292                           | 356                           | 432                           | 559                           | 660                           | 787                           | 838                           | 889                           | 991                           | 1092                           | 1194                           | 1397                           |
| 305                           | 356                           | 457                           | 610                           | 914                           |                               |                               |                               |                               |                                |                                |                                |
| 533                           | 686                           | 838                           | 1118                          | 1194                          |                               |                               |                               |                               |                                |                                |                                |
| 292                           | 356                           | 432                           | 559                           | 660                           | 787                           | 838                           |                               |                               |                                |                                |                                |
| <sup>L</sup> 292 <sup>S</sup> | <sup>L</sup> 356 <sup>S</sup> | <sup>L</sup> 432 <sup>S</sup> | <sup>L</sup> 559 <sup>S</sup> | <sup>L</sup> 660 <sup>S</sup> | <sup>L</sup> 787 <sup>S</sup> | <sup>L</sup> 838 <sup>S</sup> | <sup>S</sup> 889 <sup>T</sup> | <sup>S</sup> 991 <sup>T</sup> | <sup>S</sup> 1092 <sup>T</sup> | <sup>S</sup> 1194 <sup>T</sup> | <sup>S</sup> 1397 <sup>T</sup> |


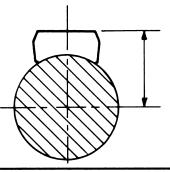
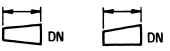
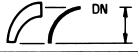


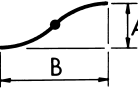
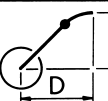
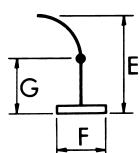
- DIMENSIONS FOR COMBINATIONS OF FITTINGS AND INSTALLED WELDOLETS DO NOT INCLUDE THE 'WELD GAP' - REFER TO TEXT: SECTION 5.3.5
- DIMENSIONS IN THIS TABLE ARE NOMINAL AND FOR COMBINATIONS OF FITTINGS ARE ROUNDED TO 1 mm
- 'H', 'I', 'J' AND 'L' ARE THE LARGEST DIMENSIONS FOR MANUALLY-OPERATED CAST-STEEL VALVES FROM A SELECTION OF MANUFACTURERS
- GUIDELINES FOR THE USE OF GEAR AND POWERED OPERATORS WITH VALVES ARE GIVEN IN SECTION 3.1.2. OF THE TEXT

**CLASS****300****BUTT-WELDED PIPING DIMENSIONS****TABLE D-2M**

DIMENSIONS IN THIS TABLE INCLUDE 1.6 mm RAISED FACE ON FLANGES

**NOMINAL DIAMETER (DN)****50 80 100 150 200 250 300 350 400 450 500 600****FITTINGS**

DIMENSIONS FROM ANSI B16.5, B16.9, B16.28 AND MANUFACTURERS DATA


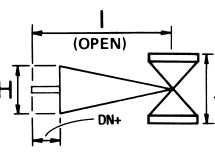

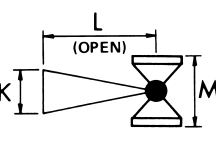

|   |                              |   |
|---|------------------------------|---|
| <b>STRAIGHT TEE</b>                                 | TABLE D-6M FOR REDUCING TEES |    |
| <b>Weldolet</b>                                     | STANDARD AND EXTRA-STRONG    |    |
| <b>REDUCERS</b>                                     | CONCENTRIC & ECCENTRIC       |    |
| <b>90° LR ELLS</b>                                  | REGULAR & REDUCING           |    |
| <b>90° SR ELL</b>                                   |                              |    |
| <b>45° ELL (LR)</b>                                 |                              |    |
| <b>OFFSET (TWO 45° ELLS)</b>                        |                              |    |
| <b>ROLLED-ELL (45° ELL + 90° LR ELL)</b>            |                              |    |
| <b>90° LR ELL + WELDING-NECK RAISED-FACE FLANGE</b> |                              |  |

**BRANCH DIAMETER**  
**50**  
**80**  
**100**

|                  |     |     |     |     |     |     |     |     |     |      |      |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| 64               | 86  | 105 | 143 | 178 | 216 | 254 | 279 | 305 | 343 | 381  | 432  |
| 68               | 83  | 95  | 122 | 148 | 175 | 200 | 216 | 241 | 267 | 292  | 343  |
| -                | 89  | 102 | 129 | 154 | 181 | 206 | 222 | 248 | 273 | 298  | 349  |
| -                | -   | 108 | 135 | 160 | 187 | 213 | 229 | 254 | 279 | 305  | 356  |
| Swage-Table D-4M | 89  | 102 | 140 | 152 | 178 | 203 | 330 | 356 | 381 | 508  | 508  |
| 76               | 114 | 152 | 229 | 305 | 381 | 457 | 533 | 610 | 686 | 762  | 914  |
| 51               | 76  | 102 | 152 | 203 | 254 | 305 | 356 | 406 | 457 | 508  | 610  |
| 35               | 51  | 64  | 95  | 127 | 159 | 190 | 222 | 254 | 286 | 318  | 381  |
| 49               | 72  | 90  | 135 | 180 | 225 | 269 | 314 | 359 | 404 | 449  | 539  |
| 119              | 173 | 217 | 325 | 434 | 542 | 650 | 759 | 867 | 976 | 1084 | 1301 |
| 79               | 117 | 153 | 229 | 305 | 382 | 458 | 534 | 611 | 687 | 763  | 916  |
| 114              | 168 | 216 | 324 | 432 | 540 | 648 | 757 | 865 | 973 | 1081 | 1297 |
| 146              | 194 | 238 | 327 | 416 | 498 | 587 | 676 | 756 | 845 | 924  | 1083 |
| 165              | 210 | 254 | 318 | 381 | 444 | 521 | 584 | 648 | 711 | 775  | 914  |
| 70               | 79  | 86  | 98  | 111 | 117 | 130 | 143 | 146 | 159 | 162  | 168  |

**VALVES**

DIMENSIONS FROM ANSI B16.10 AND MANUFACTURERS DATA

|              |   |   |
|--------------|---|---|
| <b>PLUG</b>  | VENTURI PATTERN: DN 50-600<br>SHORT PATTERN: DN 50-300<br>REGULAR PATTERN: DN 350-600 |  |
| <b>GATE</b>  | DIMENSIONS ALSO APPLY TO GATE VALVES WITH BUTT-WELDING ENDS                           |  |
| <b>BALL</b>  | LONG PATTERN: DN 50-600<br>SHORT PATTERN: DN 50-150                                   |  |
| <b>GLOBE</b> | DIMENSIONS ALSO APPLY TO GLOBE VALVES WITH BUTT-WELDING ENDS                          |  |
| <b>CHECK</b> | SWING: DN 50-600<br>TILTING DISC: DN 50-300<br>LIFT: DN 50-150, 250-300               |  |

**H**  
**I**  
**J**  
**K**  
**L**  
**M**

|                               |                               |                               |                               |                               |                               |                               |                               |                               |                               |                               |                                |
|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|
| <sup>S</sup> 216 <sup>V</sup> | <sup>S</sup> 283 <sup>V</sup> | <sup>S</sup> 305 <sup>V</sup> | <sup>S</sup> 403 <sup>V</sup> | <sup>S</sup> 419 <sup>V</sup> | <sup>S</sup> 457 <sup>V</sup> | <sup>S</sup> 502 <sup>V</sup> | <sup>R</sup> 762 <sup>V</sup> | <sup>R</sup> 838 <sup>V</sup> | <sup>R</sup> 914 <sup>V</sup> | <sup>R</sup> 991 <sup>V</sup> | <sup>R</sup> 1143 <sup>V</sup> |
| 203                           | 254                           | 305                           | 406                           | 508                           | 610                           | 610                           | 711                           | 711                           | 813                           | 914                           | 914                            |
| 533                           | 635                           | 737                           | 991                           | 1245                          | 1499                          | 1702                          | 1930                          | 2057                          | 2337                          | 2591                          | 3124                           |
| 216                           | 283                           | 305                           | 403                           | 419                           | 457                           | 502                           | 762                           | 838                           | 914                           | 991                           | 1143                           |
| <sup>L</sup> 216 <sup>S</sup> | <sup>L</sup> 283 <sup>S</sup> | <sup>L</sup> 305 <sup>S</sup> | <sup>L</sup> 403 <sup>S</sup> | <sup>L</sup> 502              | <sup>L</sup> 568              | <sup>L</sup> 648              | <sup>L</sup> 762              | <sup>L</sup> 838              | <sup>L</sup> 914              | <sup>L</sup> 991              | <sup>L</sup> 1143              |
| 254                           | 305                           | 356                           | 559                           | 610                           | 660                           | 914                           |                               |                               |                               |                               |                                |
| 508                           | 610                           | 686                           | 813                           | 1041                          | 1245                          | 1321                          |                               |                               |                               |                               |                                |
| 267                           | 318                           | 356                           | 444                           | 559                           | 622                           | 711                           |                               |                               |                               |                               |                                |
| <sup>S</sup> 267 <sup>T</sup> | <sup>S</sup> 318 <sup>T</sup> | <sup>S</sup> 356 <sup>T</sup> | <sup>S</sup> 444 <sup>T</sup> | <sup>S</sup> 533 <sup>T</sup> | <sup>S</sup> 622 <sup>T</sup> | <sup>S</sup> 711 <sup>T</sup> | <sup>S</sup> 838              | <sup>S</sup> 864              | <sup>S</sup> 978              | <sup>S</sup> 1016             | <sup>S</sup> 1346              |

- DIMENSIONS FOR COMBINATIONS OF FITTINGS AND INSTALLED WELDOLETS DO NOT INCLUDE THE 'WELD GAP' - REFER TO TEXT: SECTION 5.3.5
- DIMENSIONS IN THIS TABLE ARE NOMINAL AND FOR COMBINATIONS OF FITTINGS ARE ROUNDED TO 1 mm
- 'H', 'I', 'J' AND 'L' ARE THE LARGEST DIMENSIONS FOR MANUALLY-OPERATED CAST-STEEL VALVES FROM A SELECTION OF MANUFACTURERS
- GUIDELINES FOR THE USE OF GEAR AND POWERED OPERATORS WITH VALVES ARE GIVEN IN SECTION 3.1.2. OF THE TEXT

CLASS

150

## BUTT-WELDED PIPING DIMENSIONS

TABLE D-3M

DIMENSIONS IN THIS TABLE INCLUDE 1.6 mm RAISED FACE ON FLANGES

## NOMINAL DIAMETER (DN)

50

80

100

150

200

250

300

350

400

450

500

600

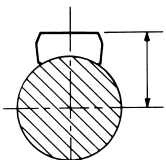
## FITTINGS

DIMENSIONS FROM ANSI B16.5, B16.9, B16.28 AND MANUFACTURERS DATA

## STRAIGHT TEE

TABLE D-6M FOR  
REDUCING TEES

## WELDOLET

STANDARD AND  
EXTRA-STRONG

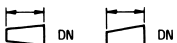
BRANCH DIAMETER

50

80

100

## REDUCERS

CONCENTRIC  
& ECCENTRIC

## 90° LR ELLS

REGULAR &  
REDUCING

## 90° SR ELL

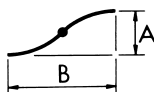


## 45° ELL (LR)



## OFFSET

(TWO 45° ELLS )

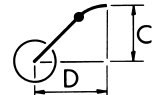


A

B

## ROLLED- ELL

(45° ELL + 90° LR ELL)



C

D

## 90° LR ELL

+ WELDING-NECK



E

F

## RAISED-FACE FLANGE

G

## VALVES

DIMENSIONS FROM ANSI B16.10 AND MANUFACTURERS DATA

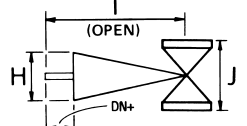
## PLUG

SHORT PATTERN: DN 50-300  
VENTURI PATTERN: DN 50-100, 350-600  
REGULAR PATTERN: DN 350-600

H

I

## GATE

REFER TO TABLE V-1M  
FOR END-TO-END  
DIMENSIONS OF GATE  
VALVES WITH BUTT-  
WELDING ENDS

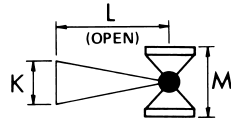
J

## BALL

LONG PATTERN: DN 50-600  
SHORT PATTERN: DN 50-400, USE 'J'  
ABOVE FOR GATE VA

K

## GLOBE

DIMENSIONS ALSO  
APPLY TO GLOBE  
VALVES WITH BUTT-  
WELDING ENDS

L

M

## CHECK

SWING: DN 50-600  
TILTING DISC: DN 50-350  
LIFT: DN 50-100, 200-350FLANGED  
& BUTT-  
WELDING

|  |  |  |                                 |  |  |  |  |                               |                               |                               |                                |
|--|--|--|---------------------------------|--|--|--|--|-------------------------------|-------------------------------|-------------------------------|--------------------------------|
| 64   | 86   | 105  | 143                             | 178  | 216  | 254  | 279  | 305                           | 343                           | 381                           | 432                            |
| 68   | 83   | 95   | 122                             | 148  | 175  | 200  | 216  | 241                           | 267                           | 292                           | 343                            |
| -  | 89   | 102  | 129                             | 154  | 181  | 206  | 222  | 248                           | 273                           | 298                           | 349                            |
| -  | -  | 108  | 135                             | 160  | 187  | 213  | 229  | 254                           | 279                           | 305                           | 356                            |
| Swage-<br>Table<br>D-4M                    | 89   | 102  | 140                             | 152  | 178  | 203  | 330  | 356                           | 381                           | 508                           | 508                            |
| 76   | 114  | 152  | 229                             | 305  | 381  | 457  | 533  | 610                           | 686                           | 762                           | 914                            |
| 51   | 76   | 102  | 152                             | 203  | 254  | 305  | 356  | 406                           | 457                           | 508                           | 610                            |
| 35   | 51   | 64   | 95                              | 127  | 159  | 190  | 222  | 254                           | 286                           | 318                           | 381                            |
| 49   | 72   | 90   | 135                             | 180  | 225  | 269  | 314  | 359                           | 404                           | 449                           | 539                            |
| 119  | 173  | 217  | 325                             | 434  | 542  | 650  | 759  | 867                           | 976                           | 1084                          | 1301                           |
| 79   | 117  | 153  | 229                             | 305  | 382  | 458  | 534  | 611                           | 687                           | 763                           | 916                            |
| 114  | 168  | 216  | 324                             | 432  | 540  | 648  | 757  | 865                           | 973                           | 1081                          | 1297                           |
| 140  | 184  | 229  | 318                             | 406  | 483  | 572  | 660  | 737                           | 826                           | 906                           | 1067                           |
| 152  | 190  | 229  | 279                             | 343  | 406  | 483  | 533  | 597                           | 635                           | 698                           | 813                            |
| 64   | 70   | 76   | 89                              | 102  | 102  | 114  | 127  | 127                           | 140                           | 144                           | 152                            |
| <sup>S</sup> 178 <sup>V</sup>              | <sup>S</sup> 203 <sup>V</sup>              | <sup>S</sup> 229 <sup>V</sup>              | <sup>S</sup> 267                | <sup>S</sup> 292                           | <sup>S</sup> 330                           | <sup>S</sup> 356                           | <sup>R</sup> 686 <sup>V</sup>              | <sup>R</sup> 762 <sup>V</sup> | <sup>R</sup> 864 <sup>V</sup> | <sup>R</sup> 914 <sup>V</sup> | <sup>R</sup> 1067 <sup>V</sup> |
| 203  | 254  | 305  | 356                             | 406  | 457  | 508  | 610  | 660                           | 762                           | 762                           | 914                            |
| 483  | 584  | 711  | 940                             | 1194                                       | 1346                                       | 1549                                       | 1803                                       | 2032                          | 2261                          | 2489                          | 2870                           |
| 178  | 203  | 229  | 267                             | 292  | 330  | 356  | 381  | 406                           | 432                           | 457                           | 508                            |
| 178  | 203  | 229  | 394                             | 457  | 533  | 610  | 686  | 762                           | 864                           | 914                           | 1067                           |
| 203  | 254  | 305  | 406                             | 457  | 610  | 914  | 914  |                               |                               |                               |                                |
| 381  | 483  | 533  | 660                             | 838  | 813  | 1067                                       | 1245                                       |                               |                               |                               |                                |
| 203  | 241  | 292  | 406                             | 495  | 622  | 698  | 787  | 914                           |                               |                               |                                |
| <sup>L</sup> 203 <sup>S</sup> <sup>T</sup> | <sup>L</sup> 241 <sup>S</sup> <sup>T</sup> | <sup>L</sup> 292 <sup>S</sup> <sup>T</sup> | - 356 <sup>S</sup> <sup>T</sup> | <sup>L</sup> 495 <sup>S</sup> <sup>T</sup> | <sup>L</sup> 622 <sup>S</sup> <sup>T</sup> | <sup>L</sup> 698 <sup>S</sup> <sup>T</sup> | <sup>L</sup> 787 <sup>S</sup> <sup>T</sup> | <sup>S</sup> 864              | <sup>S</sup> 978              | <sup>S</sup> 978              | <sup>S</sup> 1295              |

- DIMENSIONS FOR COMBINATIONS OF FITTINGS AND INSTALLED WELDOLETS DO NOT INCLUDE THE 'WELD GAP' - REFER TO TEXT: SECTION 5.3.5
- DIMENSIONS IN THIS TABLE ARE NOMINAL AND FOR COMBINATIONS OF FITTINGS ARE ROUNDED TO 1 mm
- 'H', 'I', 'J' AND 'L' ARE THE LARGEST DIMENSIONS FOR MANUALLY-OPERATED CAST-STEEL VALVES FROM A SELECTION OF MANUFACTURERS
- GUIDELINES FOR THE USE OF GEAR AND POWERED OPERATORS WITH VALVES ARE GIVEN IN SECTION 3.1.2. OF THE TEXT

## SWAGES

**TABLE D-4M**

DN (mm)

LARGE END SMALL END

50 8-40

LENGTHS: 165

65 8-50

LENGTHS: 178

80 15-65

LENGTHS: 203

90 50-80

LENGTHS: 203

100 25-90

LENGTHS: 229

125 50-100

LENGTHS: 279

150 40-125

LENGTHS: 305

200 50-150

LENGTHS: 330

250 100-200

LENGTHS: 381

LARGE END SMALL END

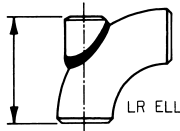
Dimensions in this table are for Mills Iron Works swages, available with ends plain, threaded, bevelled, Victaulic grooved, and in any combination of these terminations

## ELBOLETS: THREADED/SOCKET & BUTT-WELDING

DIMENSIONS IN MILLIMETERS

**TABLE D-5M**

NOMINAL DIAMETER OF MAIN RUN [DN]

| DN OF BRANCH  | 50  | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600  |
|---|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| CLASS 3000 THREADED & SOCKET-WELDING* - STD AND XS BUTT-WELDING |   |     |     |     |     |     |     |     |     |     |     |      |
| 15  | 90  | 151 | 184 | 254 | 321 | 391 | 458 | 511 | 578 | 645 | 713 | 847  |
| 20  | 122   | 158 | 191 | 261 | 329 | 398 | 465 | 518 | 585 | 652 | 720 | 854  |
| 25  | 130   | 166 | 199 | 269 | 337 | 406 | 473 | 526 | 593 | 660 | 728 | 862  |
| 40  | 141   | 177 | 210 | 280 | 348 | 417 | 484 | 537 | 604 | 672 | 739 | 873  |
| 50  | 156   | 191 | 225 | 294 | 362 | 431 | 498 | 552 | 618 | 686 | 761 | 887  |
| 80  |   | 207 | 241 | 310 | 378 | 447 | 514 | 568 | 634 | 702 | 769 | 903  |
| 100   |   |     | 258 | 328 | 395 | 464 | 532 | 585 | 652 | 719 | 787 | 921  |
| 150   |  |     |     | 371 | 438 | 507 | 575 | 628 | 695 | 762 | 829 | 964  |
| 200   |   |     |     |     | 464 | 533 | 600 | 653 | 720 | 787 | 855 | 989  |
| 250   |   |     |     |     |     | 579 | 646 | 699 | 766 | 833 | 901 | 1035 |
| 300   |   |     |     |     |     |     | 672 | 725 | 791 | 859 | 938 | 1060 |

Dimensions converted from BONNEY FORGE data. Dimensions for Elbolets are nominal. Size DN 50 Elbolets are designed to fit the different sizes of run pipe; in sizes larger than DN 50, each size of Elbolet is designed to fit a range of run pipe sizes.  
\* Threaded and socket-welding Elbolets are not available in sizes DN 150 and larger.

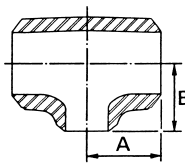
## REDUCING BUTT-WELDING TEES

WEIGHTS: STD and XS. SCH 160 thru DN 300. XXS thru DN 200

**TABLE D-6M**

NOMINAL DIAMETER OF MAIN RUN [DN]

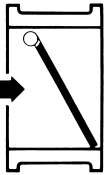
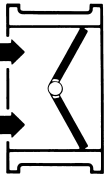
| DN            | 80  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| DIMENSION 'A' | 86  | 105 | 143 | 178 | 216 | 254 | 279 | 305 | 343 | 381 | 432 |
| DN OF BRANCH  | 50  | 76  | 89  |     |     |     |     |     |     |     |     |
|               | 80  |     | 98  | 124 |     |     |     |     |     |     |     |
|               | 100 |     |     | 130 | 156 | 184 |     |     |     |     |     |
|               | 150 |     |     |     | 168 | 194 | 219 | 238 | 264 |     |     |
|               | 200 |     |     |     |     | 203 | 229 | 248 | 273 | 298 | 324 |
|               | 250 |     |     |     |     |     | 241 | 257 | 283 | 308 | 333 |
|               | 300 |     |     |     |     |     |     | 270 | 295 | 321 | 346 |
|               | 350 |     |     |     |     |     |     |     | 305 | 330 | 356 |
|               | 400 |     |     |     |     |     |     |     |     | 330 | 356 |
|               | 450 |     |     |     |     |     |     |     |     |     | 368 |
|               | 500 |     |     |     |     |     |     |     |     |     | 432 |



# CHECK VALVES - WAFER-TYPE

## TABLE D-7M

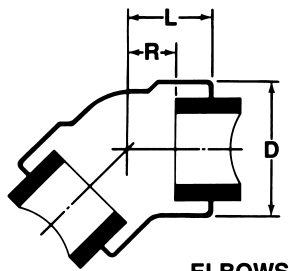
FACE-TO-FACE DIMENSIONS BY CLASS FOR VALVES CONFORMING TO API 594

| DN  | F L A N G E C L A S S E S |     |     |     |      |   |
|-----|---------------------------|-----|-----|-----|------|---|
|     | 150                       | 300 | 600 | 900 | 1500 | 2500  |
| 50  | 60                        | 60  | 60  | 70  | 70   | 70  |
| 80  | 73                        | 73  | 73  | 83  | 83   | 86  |
| 100 | 73                        | 73  | 79  | 102 | 102  | 105   |
| 150 | 98                        | 98  | 136 | 159 | 159  | 159   |
| 200 | 127                       | 127 | 165 | 206 | 206  | 206   |
| 250 | 146                       | 146 | 213 | 241 | 248  | 254   |
| 300 | 181                       | 181 | 229 | 292 | 305  | 305   |
| 350 | 184                       | 222 | 273 | 356 | 356  |  <p>SINGLE AND<br/>DUAL PLATES</p>  |
| 400 | 190                       | 232 | 305 | 384 | 384  |   |
| 450 | 203                       | 264 | 362 | 451 | 468  |   |
| 500 | 219                       | 292 | 368 | 451 | 533  |   |
| 600 | 222                       | 318 | 438 | 495 | 559  |   |

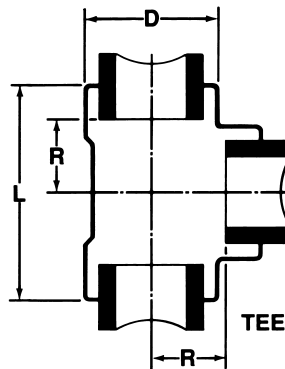
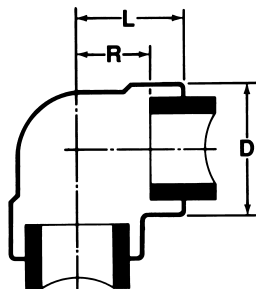
# SOCKET WELDING FITTINGS - FORGED STEEL

'R' DIMENSIONS INCLUDE  
EXPANSION GAP - NOTE 1

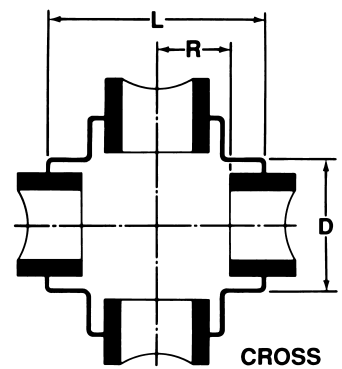
TABLE D-8M



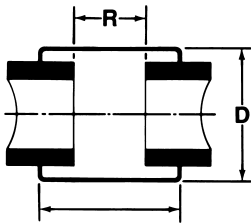
ELBOWS



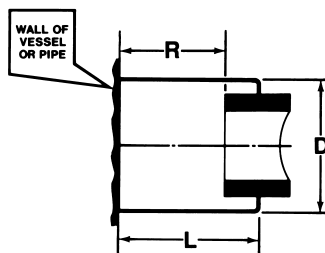
TEE



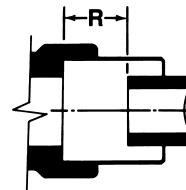
CROSS



FULL-COUPLING



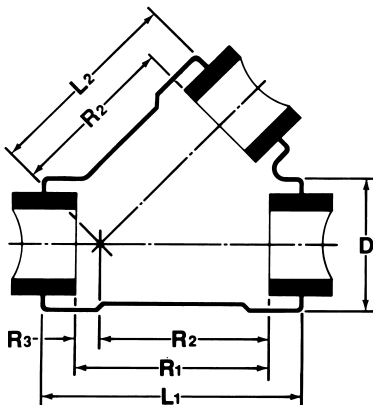
HALF-COUPLING



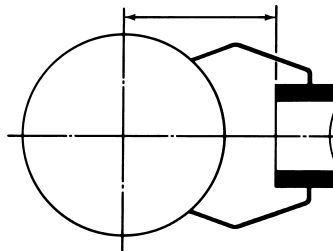
REDUCER INSERT



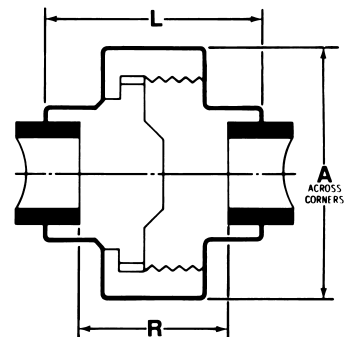
SWAGE



LATERAL



SOCKOLET (REDUCING)



UNION

| PRESSURE CLASS                  |   | 3000 |    |    |    |    | 6000 |    |    |    |    | 9000<br>[Bonney Forge] |    |    |    |    |
|---------------------------------|---|------|----|----|----|----|------|----|----|----|----|------------------------|----|----|----|----|
| NOMINAL DIAMETER<br>(DN)        |   | 15   | 20 | 25 | 40 | 50 | 15   | 20 | 25 | 40 | 50 | 15                     | 20 | 25 | 40 | 50 |
| 45 ELL                          | R | 13   | 15 | 16 | 23 | 27 | 15   | 16 | 19 | 27 | 31 | 18                     | 21 | 23 | 27 | 31 |
|                                 | L | 25   | 29 | 32 | 35 | 43 | 29   | 32 | 33 | 43 | 44 | 32                     | 33 | 35 | 44 | 52 |
| 90 ELL, CROSS<br>& STRAIGHT TEE | R | 18   | 21 | 24 | 34 | 40 | 21   | 24 | 29 | 40 | 43 | 27                     | 31 | 34 | 40 | 56 |
|                                 | L | 29   | 33 | 38 | 51 | 60 | 33   | 38 | 44 | 60 | 64 | 38                     | 44 | 51 | 64 | 83 |

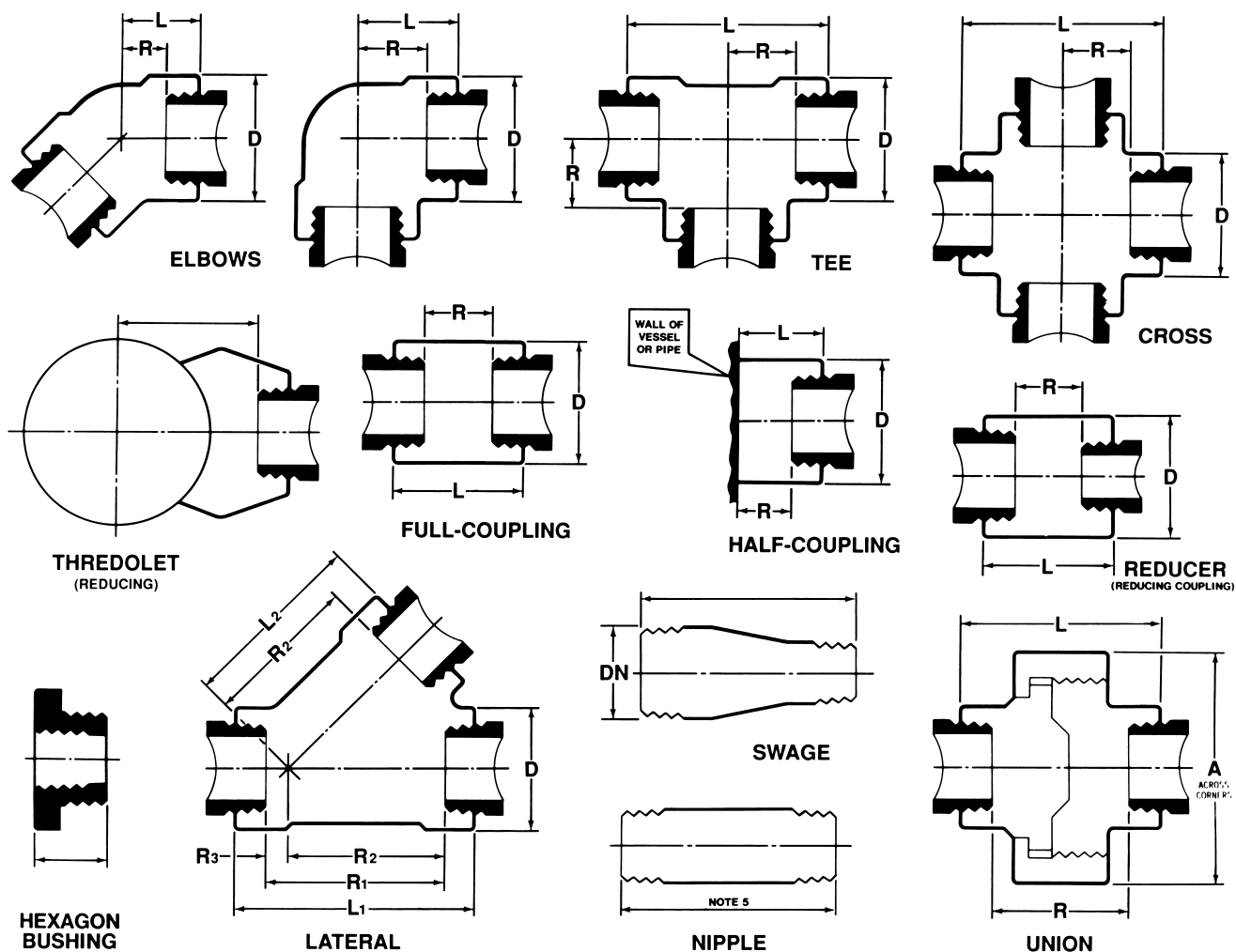
| FULL-COUPLING           |                            | R  | 14 | 14 | 17  | 17  | 23  | 14 | 14  | 17  | 17  | 23  | 14  | 14  | 17  | 17  | 23  |
|-------------------------|----------------------------|----|----|----|-----|-----|-----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                         |                            | L  | 35 | 38 | 44  | 51  | 64  | 35 | 38  | 44  | 51  | 64  | 35  | 38  | 44  | 51  | 64  |
| HALF-COUPLING           |                            | R  | 24 | 26 | 31  | 34  | 43  | 24 | 26  | 31  | 34  | 43  | 24  | 26  | 31  | 34  | 45  |
|                         |                            | L  | 35 | 38 | 44  | 51  | 64  | 35 | 38  | 44  | 51  | 64  | 35  | 38  | 44  | 51  | 64  |
| REDUCER<br>INSERT       | 15                         | R  |    | 24 | 18  | 23  | 27  |    | 29  | 31  | 29  | 31  |     | 32  | 31  | 27  | 31  |
|                         | 20                         |    |    |    | 26  | 21  | 26  |    |     | 31  | 27  | 29  |     |     | 34  | 27  | 29  |
|                         | 25                         |    |    |    |     | 19  | 24  |    |     |     | 32  | 27  |     |     | 37  | 27  |     |
|                         | 40                         |    |    |    |     |     | 34  |    |     |     | 50  |     |     |     | 54  |     |     |
| [Bonney Forge]          |                            |    |    |    |     |     |     |    |     |     |     |     |     |     |     |     |     |
| LATERAL                 |                            | R1 | 55 | 66 | 77  | 102 | 123 | 66 | 77  | 91  | 123 | 188 | 80  | 94  | 106 | 128 |     |
|                         |                            | R2 | 43 | 53 | 62  | 83  | 100 | 53 | 62  | 73  | 100 | 154 | 64  | 75  | 85  | 107 |     |
|                         |                            | R3 | 12 | 13 | 15  | 19  | 23  | 13 | 15  | 18  | 23  | 34  | 16  | 19  | 21  | 21  |     |
|                         |                            | L1 | 76 | 90 | 105 | 137 | 164 | 90 | 105 | 122 | 164 | 229 | 105 | 122 | 137 | 168 |     |
|                         |                            | L2 | 54 | 65 | 76  | 100 | 121 | 65 | 76  | 89  | 121 | 175 | 76  | 89  | 100 | 127 |     |
| [Bonney Forge & Ladish] |                            |    |    |    |     |     |     |    |     |     |     |     |     |     |     |     |     |
| DIAMETER                |                            | D  | 33 | 40 | 48  | 64  | 78  | 40 | 47  | 57  | 78  | 92  | 47  | 56  | 64  | 86  | 102 |
| SOCKOLET<br>(REDUCING)  | B<br>R<br>A<br>N<br>C<br>H | 15 |    | 30 | 33  | 40  | 46  |    | 38  | 41  | 48  | 54  |     | 37  | 40  | 48  | 54  |
|                         |                            | 20 |    |    | 33  | 40  | 46  |    |     | 41  | 48  | 54  |     |     | 43  | 50  | 56  |
|                         |                            | 25 |    |    |     | 46  | 52  |    |     |     | 50  | 56  |     |     | 52  | 58  |     |
|                         |                            | 40 |    |    |     |     | 51  |    |     |     | 54  |     |     |     | 62  |     |     |
| [Bonney Forge]          |                            |    |    |    |     |     |     |    |     |     |     |     |     |     |     |     |     |
| UNION                   |                            | R  | 32 | 33 | 39  | 52  | 56  | 33 | 39  | 47  | 56  | 64  |     |     |     |     |     |
|                         |                            | L  | 51 | 59 | 62  | 76  | 89  | 59 | 62  | 73  | 89  | 105 |     |     |     |     |     |
|                         |                            | A  | 49 | 60 | 71  | 94  | 112 | 60 | 71  | 85  | 112 | 133 |     |     |     |     |     |
| [Bonney Forge]          |                            |    |    |    |     |     |     |    |     |     |     |     |     |     |     |     |     |
| SWAGE                   |                            |    | 70 | 76 | 89  | 114 | 165 | 70 | 76  | 89  | 114 | 165 | 70  | 76  | 89  | 114 | 165 |

- (1) 'R' DIMENSIONS ('REMOVED RUN' OF PIPE) HAVE BEEN ROUNDED TO 1.0 mm AND INCLUDE 2 mm EXPANSION GAP(S) FOR WELDING. REFER TO 'SOCKET-WELDING PIPING' - CHART 2.2
- (2) DIMENSIONS ARE FROM THE FOLLOWING SUPPLIERS' DATA: BONNEY FORGE, ITT GRINNELL, LADISH AND VOGT
- (3) UNLESS THE SUPPLIER IS STATED, 'L' & 'D' DIMENSIONS ARE THE LARGEST QUOTED BY BONNEY FORGE, ITT GRINNELL, LADISH AND VOGT
- (4) FITTINGS CONFORM TO ANSI B16.11, EXCEPT LATERALS AND REDUCER INSERTS, WHICH ARE MADE TO MANUFACTURERS' STANDARDS
- (5) FOR INFORMATION ON THE BORE DIAMETER AND RATING OF FITTINGS, REFER TO 'SOCKET-WELDED PIPING' - CHART 2.2
- (6) UNIONS CONFORM TO MSS-SP-83
- (7) DIMENSIONS FOR INSTALLED SOCKOLETS EXCLUDE THE 'ROOT GAP' - REFER TO 'DIMENSIONING SPOOLS (WELDED ASSEMBLIES)' - 5.3.5

# THREADED FITTINGS - FORGED STEEL

DIMENSIONS  
IN  
MILLIMETERS

TABLE D-9M



| PRESSURE CLASS               |   | 2000 |    |    |    |    | 3000 |    |    |    |    | 6000 |    |    |    |    |
|------------------------------|---|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|
| NOMINAL DIAMETER (DN)        |   | 15   | 20 | 25 | 40 | 50 | 15   | 20 | 25 | 40 | 50 | 15   | 20 | 25 | 40 | 50 |
| 45 ELL                       | R | 11   | 13 | 13 | 17 | 25 | 14   | 16 | 16 | 25 | 25 | 17   | 19 | 17 | 27 | 33 |
|                              | L | 24   | 27 | 30 | 35 | 44 | 27   | 30 | 33 | 43 | 44 | 30   | 33 | 35 | 44 | 52 |
| 90 ELL, CROSS & STRAIGHT TEE | R | 16   | 19 | 21 | 33 | 41 | 21   | 24 | 27 | 43 | 44 | 25   | 30 | 33 | 46 | 64 |
|                              | L | 29   | 33 | 38 | 51 | 60 | 33   | 38 | 44 | 60 | 64 | 38   | 44 | 51 | 64 | 83 |
| FULL-COUPLING                | R |      |    |    |    |    | 22   | 22 | 25 | 44 | 48 | 22   | 22 | 25 | 44 | 48 |
|                              | L |      |    |    |    |    | 48   | 51 | 60 | 79 | 86 | 48   | 51 | 60 | 79 | 86 |

| HALF-COUPLING           |                            | R                       |    |    |     |     |     | 11  | 11  | 13  | 22  | 24  | 11  | 11  | 13  | 22  | 24  |
|-------------------------|----------------------------|-------------------------|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                         |                            | L                       |    |    |     |     |     | 24  | 25  | 30  | 40  | 43  | 24  | 25  | 30  | 40  | 43  |
| REDUCER                 | 15                         | R                       |    |    |     |     |     |     | 24  | 30  | 49  | 54  |     | 24  | 30  | 49  | 54  |
|                         | 20                         |                         |    |    |     |     |     |     |     | 29  | 48  | 52  |     |     | 29  | 48  | 52  |
|                         | 25                         |                         |    |    |     |     |     |     |     |     | 44  | 49  |     |     |     | 44  | 49  |
|                         | 40                         |                         |    |    |     |     |     |     |     |     |     | 49  |     |     |     |     | 49  |
|                         |                            | L                       |    |    |     |     |     |     | 51  | 60  | 79  | 86  |     | 51  | 60  | 79  | 86  |
| LATERAL                 |                            | R1                      | 53 | 63 | 72  | 105 | 129 | 67  | 78  | 90  | 132 | 191 | 81  | 97  | 105 | 194 | 194 |
|                         |                            | R2                      | 42 | 51 | 59  | 84  | 103 | 53  | 63  | 73  | 105 | 156 | 64  | 76  | 84  | 157 | 159 |
|                         |                            | R3                      | 10 | 12 | 12  | 21  | 25  | 13  | 15  | 17  | 27  | 35  | 17  | 21  | 21  | 37  | 35  |
|                         |                            | L1                      | 78 | 92 | 106 | 140 | 167 | 92  | 106 | 125 | 167 | 229 | 106 | 125 | 140 | 229 | 232 |
|                         |                            | [Bonney Forge & Ladish] |    | L2 | 55  | 66  | 77  | 102 | 122 | 66  | 77  | 90  | 122 | 175 | 77  | 90  | 102 |
| DIAMETER                |                            | D                       | 33 | 40 | 47  | 66  | 78  | 40  | 47  | 57  | 78  | 92  | 47  | 57  | 64  | 92  | 110 |
| THREDOLET<br>(REDUCING) | B<br>R<br>A<br>N<br>C<br>H | 15                      |    |    |     |     |     |     | 26  | 29  | 37  | 43  |     | 32  | 36  | 43  | 49  |
|                         |                            | 20                      |    |    |     |     |     |     |     | 29  | 37  | 43  |     |     | 39  | 46  | 52  |
|                         |                            | 25                      |    |    |     |     |     |     |     |     | 40  | 46  |     |     |     | 46  | 52  |
|                         |                            | 40                      |    |    |     |     |     |     |     |     |     | 48  |     |     |     |     | 56  |
| UNION                   |                            | R                       |    |    |     |     |     | 25  | 30  | 27  | 42  | 50  | 32  | 33  | 38  | 52  | 66  |
|                         |                            | L                       |    |    |     |     |     | 51  | 59  | 62  | 76  | 88  | 58  | 62  | 73  | 87  | 104 |
|                         |                            | A                       |    |    |     |     |     | 49  | 61  | 71  | 94  | 112 | 61  | 70  | 85  | 112 | 133 |
| HEX BUSH                |                            |                         | 24 | 25 | 27  | 33  | 37  | 24  | 25  | 27  | 33  | 37  | 24  | 25  | 27  | 33  | 37  |
| SWAGE                   |                            |                         | 70 | 76 | 89  | 114 | 165 | 70  | 76  | 89  | 114 | 165 | 70  | 76  | 89  | 114 | 165 |
| THREAD ENGAGEMENT       |                            |                         | 13 | 14 | 17  | 17  | 19  | 13  | 14  | 17  | 17  | 19  | 13  | 14  | 17  | 17  | 19  |

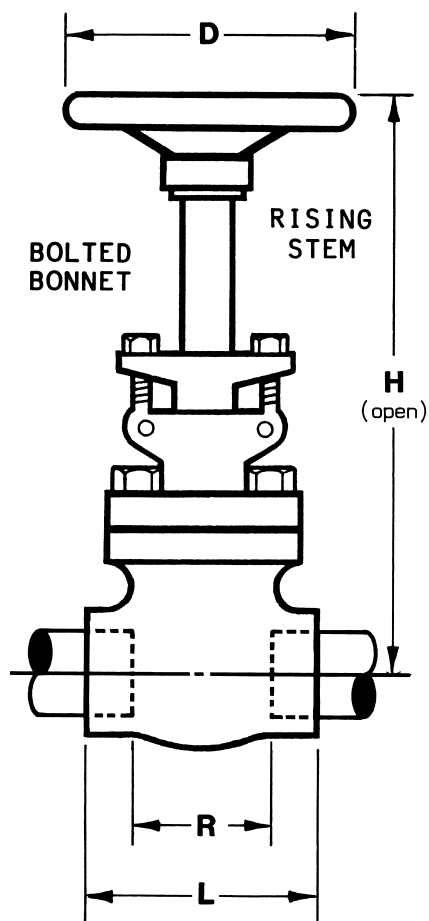
- (1) 'R' DIMENSIONS ('REMOVED RUN' OF PIPE) ARE BASED ON NORMAL THREAD ENGAGEMENT BETWEEN MALE AND FEMALE THREADS TO MAKE TIGHT JOINTS - ROUNDED TO 1.00 mm
- (2) DIMENSIONS FOR FITTINGS ARE FROM THE FOLLOWING SUPPLIERS' DATA: BONNEY FORGE, ITT GRINNEL, LADISH AND VOGT
- (3) UNLESS THE SUPPLIER IS STATED, 'L' & 'D' DIMENSIONS ARE THE LARGEST QUOTED BY BONNEY FORGE, ITT GRINNELL, LADISH AND VOGT
- (4) FITTINGS CONFORM TO ANSI B16.11, EXCEPT LATERALS, WHICH ARE MADE TO MANUFACTURERS' STANDARDS. UNIONS CONFORM TO MSS-SP-83
- (5) FOR SIZES AND AVAILABILITIES OF PIPE NIPPLES, REFER TO 'MALLEABLE-IRON PIPE FITTINGS' - TABLE D-11M
- (6) DIMENSIONS FOR INSTALLED THREDOLETS EXCLUDE THE 'ROOT GAP' - REFER TO 'DIMENSIONING SPOOLS (WELDED ASSEMBLIES)' - 5.3.5

# CLASS 800 VALVES

API CLASS 800 FORGED-STEEL  
GATE, GLOBE & CHECK VALVES

## TABLE D - 10M

DATA: SMITH VALVE CORPORATION  
GATE VALVES: FULL PORT  
GLOBE VALVES: CONVENTIONAL PORT



'R' is the 'REMOVED RUN' of  
pipe occupied by the valve

### VALVES WITH THREADED ENDS

| DN                    |    | 15  | 20  | 25  | 40  | 50  |
|-----------------------|----|-----|-----|-----|-----|-----|
| G<br>A<br>T<br>E      | D  | 102 | 102 | 140 | 168 | 168 |
|                       | H  | 162 | 184 | 217 | 279 | 317 |
|                       | L  | 89  | 98  | 108 | 140 | 144 |
|                       | R  | 64  | 70  | 73  | 105 | 106 |
| G<br>L<br>O<br>B<br>E | D  | 102 | 102 | 102 | 117 | 168 |
|                       | H  | 162 | 167 | 173 | 206 | 257 |
|                       | L* | 83  | 89  | 114 | 159 | 184 |
|                       | R* | 57  | 60  | 79  | 124 | 146 |

'R' dimensions are based on normal  
thread engagement for tight joints

\* These dimensions also apply to horizontal lift-check valves

### VALVES WITH SOCKET ENDS

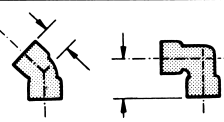
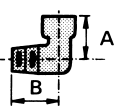

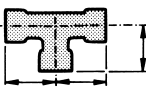

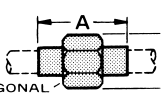
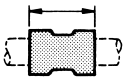

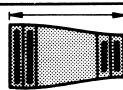
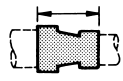
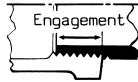
| DN                    |    | 15  | 20  | 25  | 40  | 50  |
|-----------------------|----|-----|-----|-----|-----|-----|
| G<br>A<br>T<br>E      | D  | 102 | 102 | 140 | 168 | 168 |
|                       | H  | 162 | 184 | 217 | 279 | 317 |
|                       | L  | 89  | 98  | 108 | 140 | 144 |
|                       | R  | 52  | 58  | 71  | 80  | 96  |
| G<br>L<br>O<br>B<br>E | D  | 102 | 102 | 102 | 117 | 168 |
|                       | H  | 162 | 167 | 173 | 206 | 257 |
|                       | L* | 83  | 89  | 114 | 159 | 184 |
|                       | R* | 61  | 64  | 87  | 125 | 144 |

'R' dimensions include 2 mm expansion gaps  
for welding. Refer to text: Chart 2.2

# THREADED FITTINGS - MALLEABLE-IRON

DIMENSIONS  
ROUNDED  
TO 1.00 mm

TABLE D-11M

| PRESSURE CLASS  |   | 150   |    |    |     |     |     | 300 |    |    |     |     |     |
|---|---|---|----|----|-----|-----|-----|-----|----|----|-----|-----|-----|
| NOMINAL DIAMETER [DN]                                   |   | 15  | 20 | 25 | 40  | 50  | 80  | 15  | 20 | 25 | 40  | 50  | 80  |
| 45° ELL   |    | 22  | 25 | 29 | 37  | 43  | 56  | 25  | 29 | 33 | 43  | 51  | 64  |
| 90° ELL   |   | 29  | 33 | 38 | 49  | 57  | 78  | 32  | 37 | 41 | 54  | 64  | 86  |
| 90° STREET ELL  |    | 29  | 33 | 38 | 49  | 57  | 78  | 32  | 37 | 41 | 54  | 64  | 86  |
|   |   | 41  | 48 | 54 | 68  | 83  | 114 | 51  | 56 | 65 | 79  | 94  | 130 |
| RETURN BEND   |    | 25  | 32 | 38 | 56  | 67  |     |     |    |    |     |     |     |
|   |   | 32  | 38 | 48 | 64  | 76  |     |     |    |    |     |     |     |
|   |   | 38  | 51 | 64 | 89  | 102 |     |     |    |    |     |     |     |
| STRAIGHT TEE  | (These data also apply to the center-to-end dimension for straight cross.)<br> | 29  | 33 | 38 | 49  | 57  | 78  | 32  | 37 | 41 | 54  | 64  | 86  |
| LATERAL   |    | 59  | 71 | 84 | 111 | 132 | 184 |     |    |    |     |     |     |
|   |   | 43  | 52 | 62 | 83  | 100 | 141 |     |    |    |     |     |     |
| UNION   | <br>OCTAGONAL  | 49  | 52 | 62 | 70  | 75  | 95  | 52  | 57 | 65 | 76  | 86  | 108 |
|   |   | 46  | 51 | 56 | 67  | 78  | 98  | 49  | 57 | 62 | 76  | 86  | 125 |
| COUPLING  |    | 33  | 38 | 43 | 54  | 64  | 81  | 48  | 54 | 60 | 73  | 92  | 105 |
| NIPPLE<br>CARBON-STEEL<br>(TANK NIPPLES ARE 150mm LONG) |    | 30  | 35 | 40 | 45  | 50  | 65  | 30  | 35 | 40 | 45  | 50  | 65  |
|   |   | AVAILABLE IN 50, 65, 75, 90, 100, 115, 125, 140<br>150, 180, 200, 230, 255, 280 & 305 mm LENGTHS<br>(DN 15 and DN 20 nipples are also available 40 mm long) |    |    |     |     |     |     |    |    |     |     |     |
| SWAGE<br>MILLS<br>IRON<br>WORKS<br>CARBON-STEEL         | DN   | 70  | 76 | 89 | 114 | 165 | 203 | 70  | 76 | 89 | 114 | 165 | 203 |
| REDUCER   | DN   | 32  | 37 | 43 | 59  | 71  | 94  | 43  | 44 | 51 | 68  | 81  | 103 |
| THREAD ENGAGEMENT                                       | TAPER<br>TAPER<br>   | 13  | 14 | 17 | 17  | 19  | 25  | 13  | 14 | 17 | 17  | 19  | 25  |

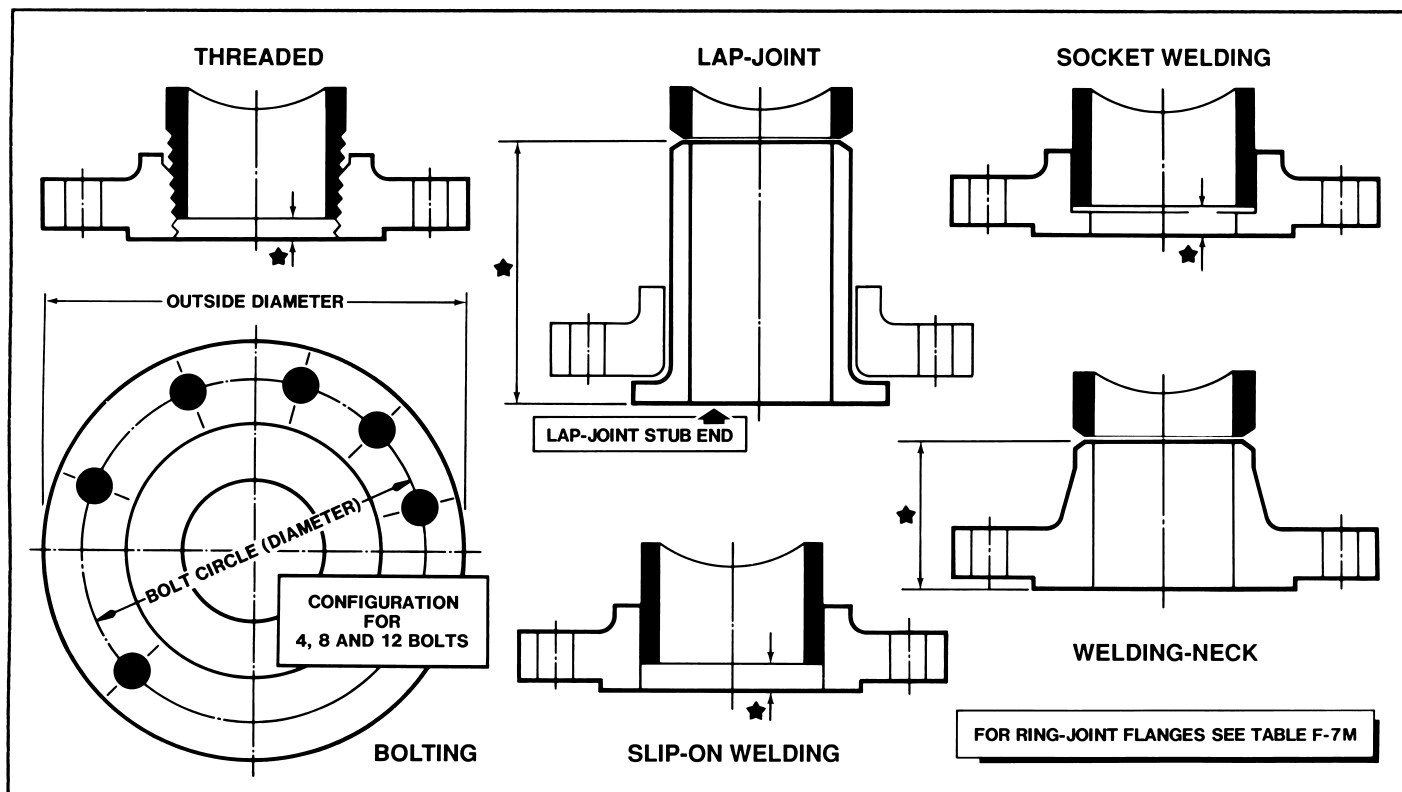
DIMENSIONS IN THIS TABLE ARE FOR BANDED FITTINGS AND CONFORM TO ANSI STANDARD B16.3, AND FEDERAL SPECIFICATION WW-P-521. UNIONS CONFORM TO ANSI B16.39. DATA FROM ITT GRINNELL CORPORATION AND STOCKHAM VALVES AND FITTINGS

# FORGED-STEEL FLANGES & LAP-JOINT STUB-ENDS

FLANGE CLASSES  
150-2500  
(PN20-PN420)

TABLES FM

DIMENSIONS IN MILLIMETERS



## NOTES

- [1] FLANGE DIMENSIONS: INTERNATIONAL STANDARD ISO 2229, ANSI STANDARD B16.5 AND MANUFACTURERS' DATA
- [2] BLIND FLANGES: DATA FOR FLANGE DIAMETERS AND BOLTING IN THESE TABLES ALSO APPLIES TO BLIND FLANGES
- [3] REDUCING FLANGES: AVAILABLE IN SLIP-ON, THREADED AND WELDING-NECK TYPES
- [4] LAP-JOINT STUB-ENDS: ANSI B16.9 (Long Pattern) & MSS SP-43 (Short Pattern)
- [5]  STUDBOLT THREAD LENGTHS FOR LAP-JOINTS

| FLANGE COMBINATION  | FLANGE CLASS | INCREASE IN STUDBOLT LENGTH OVER LENGTHS IN TABLES F-1M thru F-6M |
|---|--------------|---|
| Lapped to non-lapped                                      | 150 or 300   | Thickness of lap  |
|   | Over 300     | Thickness of lap minus 6.4 mm                                     |
| Lapped to lapped  | 150 - 2500   | Thickness of two laps   |
| Thickness of lap = Thickness of pipe wall + 0 mm + 1.6 mm |              |   |

# CLASS 150 FLANGE DATA

PN20

- DIMENSIONS INCLUDE 1.6 mm RAISED FACE ON FLANGES (except lap-joint)
- DIMENSIONS INCLUDE 2 mm GAP FOR WELDING - REFER TO CHART 2.2

# TABLE F-1M

| NOMINAL DIAMETER: DN     |  |                    | 15                            | 20   | 25   | 40   | 50    | 80    | 100   | 150   | 200   | 250   | 300   | 350                      | 400   | 450   | 500   | 600   |
|--------------------------|--|--------------------|-------------------------------|------|------|------|-------|-------|-------|-------|-------|-------|-------|--------------------------|-------|-------|-------|-------|
| OUTSIDE DIAMETER         |  |                    | 89                            | 98   | 108  | 127  | 152   | 190   | 229   | 279   | 343   | 406   | 483   | 533                      | 597   | 635   | 698   | 813   |
| FLANGE<br>TYPE           | <div>★<br/>END OF<br/>PIPE TO<br/>FACE OF<br/>FLANGE<br/>or LAP<br/>JOINT<br/>STUB<br/>END •</div> | WELD-NECK          | 48                            | 52   | 56   | 62   | 64    | 70    | 76    | 89    | 102   | 102   | 114   | 127                      | 127   | 140   | 144   | 152   |
|                          |  | SLIP-ON            | Wall thickness of pipe + 2 mm |      |      |      |       |       |       |       |       |       |       |                          |       |       |       |       |
|                          |  | SOCKET ••          | 9                             | 7    | 7    | 8    | 10    | 12    |       |       |       |       |       |                          |       |       |       |       |
|                          |  | THREADED           | 2                             | 2    | 0    | 5    | 7     | 4     | 5     | 9     | 11    | 12    | 15    |                          |       |       |       |       |
|                          |  | L-J<br>STUB<br>END | ANSI                          | 76   | 76   | 102  | 102   | 152   | 152   | 152   | 203   | 203   | 254   | 254                      | 305   | 305   | 305   | 305   |
|                          | MSS  |                    | 51                            | 51   | 51   | 51   | 64    | 64    | 76    | 89    | 102   | 127   | 152   | 152                      | 152   | 152   | 152   | 152   |
| BORE: WELD-NECK & SOCKET |  |                    | 15.8                          | 21   | 26.2 | 40.9 | 52.5  | 77.9  | 102.3 | 154.1 | 202.7 | 254.5 | 304.9 | [Order to match pipe ID] |       |       |       |       |
| BOLTING                  | BOLTS PER FLANGE   |                    | 4                             | 4    | 4    | 4    | 4     | 4     | 8     | 8     | 8     | 12    | 12    | 12                       | 16    | 16    | 20    | 20    |
|                          | BOLT CIRCLE DIAMETER   |                    | 60.3                          | 69.8 | 79.4 | 98.4 | 120.6 | 152.4 | 190.5 | 241.3 | 298.4 | 362   | 431.8 | 476.2                    | 539.8 | 577.8 | 635   | 749.3 |
|                          | DIAMETER OF BOLT (IN)  |                    | 1/2                           | 1/2  | 1/2  | 1/2  | 5/8   | 5/8   | 5/8   | 3/4   | 3/4   | 7/8   | 7/8   | 1                        | 1     | 1 1/8 | 1 1/8 | 1 1/4 |
|                          | STUBBOLT THREAD<br>length - except<br>lap-joint: Note 5  | RF                 | 57                            | 57   | 64   | 70   | 76    | 89    | 89    | 95    | 102   | 114   | 114   | 127                      | 133   | 146   | 152   | 171   |
|                          |  | RJ                 | -                             | -    | 76   | 83   | 89    | 102   | 102   | 108   | 114   | 127   | 127   | 140                      | 146   | 159   | 165   | 184   |

PN references are discussed under 'FLANGE CLASSES and PRESSURE NUMBERS'- page 233

# CLASS 300 FLANGE DATA

PN50

- DIMENSIONS INCLUDE 1.6 mm RAISED FACE ON FLANGES (except lap-joint)
- DIMENSIONS INCLUDE 2 mm GAP FOR WELDING - REFER TO CHART 2.2

# TABLE F-2M


| NOMINAL DIAMETER: DN     |   |                    | 15                            | 20   | 25   | 40    | 50   | 80    | 100   | 150   | 200   | 250   | 300   | 350                      | 400   | 450   | 500   | 600   |     |
|--------------------------|---|--------------------|-------------------------------|------|------|-------|------|-------|-------|-------|-------|-------|-------|--------------------------|-------|-------|-------|-------|-----|
| OUTSIDE DIAMETER         |   |                    | 95                            | 117  | 124  | 156   | 165  | 210   | 254   | 318   | 381   | 444   | 521   | 584                      | 648   | 711   | 775   | 914   |     |
| FLANGE<br>TYPE           | ★<br>END OF<br>PIPE TO<br>FACE OF<br>FLANGE<br>or LAP<br>JOINT<br>STUB<br>END • | WELD-NECK          | 52                            | 57   | 62   | 68    | 70   | 79    | 86    | 98    | 111   | 117   | 130   | 143                      | 146   | 159   | 162   | 168   |     |
|                          |   | SLIP-ON            | Wall thickness of pipe + 2 mm |      |      |       |      |       |       |       |       |       |       |                          |       |       |       |       |     |
|                          |   | SOCKET ••          | 15                            | 16   | 17   | 16    | 18   | 25    |       |       |       |       |       |                          |       |       |       |       |     |
|                          |   | THREADED           | 2                             | 2    | 0    | 5     | 11   | 6     | 9     | 15    | 18    | 19    | 19    |                          |       |       |       |       |     |
|                          |   | L-J<br>STUB<br>END | ANSI                          | 76   | 76   | 102   | 102  | 152   | 152   | 152   | 203   | 203   | 254   | 254                      | 305   | 305   | 305   | 305   |     |
|                          |   |                    | MSS                           | 51   | 51   | 51    | 51   | 64    | 64    | 76    | 89    | 102   | 127   | 152                      | 152   | 152   | 152   | 152   | 152 |
| BORE: WELD-NECK & SOCKET |   |                    | 15.8                          | 21   | 26.2 | 40.9  | 52.5 | 77.9  | 102.3 | 154.1 | 202.7 | 254.5 | 304.9 | [Order to match pipe ID] |       |       |       |       |     |
| BOLTING                  | BOLTS PER FLANGE  |                    | 4                             | 4    | 4    | 4     | 8    | 8     | 8     | 12    | 12    | 16    | 16    | 20                       | 20    | 24    | 24    | 24    |     |
|                          | BOLT CIRCLE DIAMETER  |                    | 66.7                          | 82.6 | 88.9 | 114.3 | 127  | 168.3 | 200   | 269.9 | 330.2 | 387.4 | 450.8 | 514.4                    | 571.5 | 628.6 | 685.8 | 812.8 |     |
|                          | DIAMETER OF BOLT (IN)   |                    | 1/2                           | 5/8  | 5/8  | 3/4   | 5/8  | 3/4   | 3/4   | 3/4   | 7/8   | 1     | 1 1/8 | 1 1/8                    | 1 1/4 | 1 1/4 | 1 1/4 | 1 1/4 |     |
|                          | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5                         | RF                 | 64                            | 70   | 76   | 89    | 83   | 102   | 108   | 121   | 133   | 152   | 165   | 171                      | 184   | 190   | 203   | 229   |     |
|                          |   | RJ                 | 76                            | 83   | 89   | 102   | 102  | 121   | 127   | 140   | 152   | 171   | 184   | 190                      | 203   | 210   | 222   | 254   |     |

# CLASS 600 FLANGE DATA

PN100

- DIMENSIONS INCLUDE 6.4 mm RAISED FACE ON FLANGES (except lap-joint)
- DIMENSIONS INCLUDE 2 mm GAP FOR WELDING - REFER TO CHART 2.2

# TABLE F-3M

| NOMINAL DIAMETER: DN                               |   |                    | 15                                       | 20                            | 25   | 40    | 50  | 80    | 100   | 150   | 200   | 250   | 300   | 350   | 400   | 450   | 500   | 600   |     |     |
|--|---|--------------------|--|-------------------------------|------|-------|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|-----|
| OUTSIDE DIAMETER                                   |   |                    | 95                                       | 117                           | 124  | 156   | 165 | 210   | 273   | 356   | 419   | 508   | 559   | 603   | 686   | 743   | 813   | 940   |     |     |
| F<br>L<br>A<br>N<br>G<br>E<br><br>T<br>Y<br>P<br>E | <br>END OF<br>PIPE TO<br>FACE OF<br>FLANGE<br>or LAP<br>JOINT<br>STUB<br>END • | WELD-NECK          |  | 58                            | 63   | 68    | 76  | 79    | 89    | 108   | 123   | 139   | 158   | 162   | 171   | 184   | 190   | 196   | 209 |     |
|  |   | SLIP-ON            |  | Wall thickness of pipe + 2 mm |      |       |     |       |       |       |       |       |       |       |       |       |       |       |     |     |
|  |   | SOCKET ••          |  | 21                            | 22   | 23    | 24  | 28    | 34    |       |       |       |       |       |       |       |       |       |     |     |
|  |   | THREADED           |  | 9                             | 8    | 7     | 11  | 18    | 12    | 15    | 22    | 24    | 25    | 26    |       |       |       |       |     |     |
|  |   | L-J<br>STUB<br>END | ANSI                                     | 76                            | 76   | 102   | 102 | 152   | 152   | 152   | 203   | 203   | 254   | 254   | 305   | 305   | 305   | 305   | 305 | 305 |
|  |   |                    | MSS                                      | 51                            | 51   | 51    | 51  | 64    | 64    | 76    | 89    | 102   | 127   | 152   | 152   | 152   | 152   | 152   | 152 | 152 |
| BORE: WELD-NECK & SOCKET                           |   |                    | Order to match Internal Diameter of Pipe |                               |      |       |     |       |       |       |       |       |       |       |       |       |       |       |     |     |
| B<br>O<br>L<br>T<br>I<br>N<br>G                    | BOLTS PER FLANGE  |                    | 4  | 4                             | 4    | 4     | 8   | 8     | 8     | 12    | 12    | 16    | 20    | 20    | 20    | 20    | 24    | 24    |     |     |
|  | BOLT CIRCLE DIAMETER  |                    | 66.7                                     | 82.6                          | 88.9 | 114.3 | 127 | 168.3 | 215.9 | 292.1 | 349.2 | 431.8 | 489   | 527   | 603.2 | 654   | 723.9 | 838.2 |     |     |
|  | DIAMETER OF BOLT (IN)   |                    | 1/2                                      | 5/8                           | 5/8  | 3/4   | 5/8 | 3/4   | 7/8   | 1     | 1 1/8 | 1 1/4 | 1 1/4 | 1 3/8 | 1 1/2 | 1 5/8 | 1 5/8 | 1 7/8 |     |     |
|  | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5   | RF                 | 76                                       | 83                            | 89   | 102   | 102 | 121   | 140   | 165   | 190   | 210   | 216   | 229   | 248   | 267   | 286   | 324   |     |     |
|  |   | RJ                 | 76                                       | 83                            | 89   | 102   | 108 | 127   | 146   | 171   | 197   | 216   | 222   | 235   | 254   | 273   | 292   | 337   |     |     |


PN references are discussed under 'FLANGE CLASSES and PRESSURE NUMBERS' - page 233

# CLASS 900 FLANGE DATA

PN150

- DIMENSIONS INCLUDE 6.4 mm RAISED FACE ON FLANGES (except lap-joint)

# TABLE F-4M

| NOMINAL DIAMETER: DN                               |   |                    | 15                                       | 20                            | 25    | 40    | 50    | 80    | 100   | 150   | 200   | 250   | 300   | 350   | 400   | 450   | 500   | 600   |     |     |
|--|---|--------------------|--|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|-----|
| OUTSIDE DIAMETER                                   |   |                    | 121                                      | 130                           | 149   | 178   | 216   | 241   | 292   | 381   | 470   | 546   | 610   | 641   | 705   | 787   | 857   | 1041  |     |     |
| F<br>L<br>A<br>N<br>G<br>E<br><br>T<br>Y<br>P<br>E | <br>END OF<br>PIPE TO<br>FACE OF<br>FLANGE<br>or LAP<br>JOINT<br>STUB<br>END • | WELD-NECK          |  | 66                            | 76    | 79    | 89    | 108   | 108   | 120   | 146   | 168   | 190   | 206   | 219   | 222   | 235   | 254   | 298 |     |
|  |   | SLIP-ON            |  | Wall thickness of pipe + 2 mm |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |     |
|  |   | SOCKET             |  | Not available in this class   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |     |
|  |   | THREADED           |  | 15                            | 17    | 19    | 21    | 27    | 12    | 16    | 22    | 24    | 24    | 26    |       |       |       |       |     |     |
|  |   | L-J<br>STUB<br>END | ANSI                                     | 76                            | 76    | 102   | 102   | 152   | 152   | 152   | 203   | 203   | 254   | 254   | 305   | 305   | 305   | 305   | 305 | 305 |
|  |   |                    | MSS                                      | 51                            | 51    | 51    | 51    | 64    | 64    | 76    | 89    | 102   | 127   | 152   | 152   | 152   | 152   | 152   | 152 | 152 |
| BORE: WELD-NECK                                    |   |                    | Order to match Internal Diameter of Pipe |                               |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |     |
| B<br>O<br>L<br>T<br>I<br>N<br>G                    | BOLTS PER FLANGE  |                    | 4  | 4                             | 4     | 4     | 8     | 8     | 8     | 12    | 12    | 16    | 20    | 20    | 20    | 20    | 20    | 20    |     |     |
|  | BOLT CIRCLE DIAMETER  |                    | 82.6                                     | 88.9                          | 101.6 | 123.8 | 165.1 | 190.5 | 235   | 317.5 | 393.7 | 469.9 | 533.4 | 558.8 | 616   | 685.8 | 749.3 | 901.7 |     |     |
|  | DIAMETER OF BOLT (IN)   |                    | 3/4                                      | 3/4                           | 7/8   | 1     | 7/8   | 7/8   | 1 1/8 | 1 1/8 | 1 3/8 | 1 3/8 | 1 3/8 | 1 1/2 | 1 5/8 | 1 7/8 | 2     | 2 1/2 |     |     |
|  | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5   | RF                 | 102                                      | 108                           | 121   | 133   | 140   | 140   | 165   | 190   | 216   | 229   | 248   | 267   | 279   | 324   | 343   | 432   |     |     |
|  |   | RJ                 | 102                                      | 108                           | 121   | 133   | 146   | 146   | 171   | 190   | 222   | 235   | 254   | 279   | 292   | 337   | 356   | 457   |     |     |

# CLASS 1500 FLANGE DATA

PN250

- DIMENSIONS INCLUDE 6.4 mm RAISED FACE ON FLANGES (except lap-joint)
- DIMENSIONS INCLUDE 2 mm GAP FOR WELDING - REFER TO CHART 2.2

TABLE F-5M

| NOMINAL DIAMETER: DN     |   |                    | 15                                       | 20   | 25    | 40    | 50    | 80    | 100   | 150   | 200   | 250   | 300   | 350   | 400   | 450   | 500   | 600   |
|--------------------------|---|--------------------|--|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| OUTSIDE DIAMETER         |   |                    | 121                                      | 130  | 149   | 178   | 216   | 267   | 311   | 394   | 483   | 584   | 673   | 749   | 826   | 914   | 984   | 1168  |
| FLANGE<br>TYPE           | ★<br>END OF<br>PIPE TO<br>FACE OF<br>FLANGE<br>or LAP<br>JOINT<br>STUB<br>END • | WELD-NECK          | 66                                       | 76   | 79    | 89    | 108   | 123   | 130   | 177   | 219   | 260   | 289   | 304   | 317   | 333   | 362   | 412   |
|                          |   | SLIP-ON            | Wall thickness of pipe + 2 mm            |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|                          |   | SOCKET ••          | 31                                       | 32   | 37    | 36    | 48    |       |       |       |       |       |       |       |       |       |       |       |
|                          |   | THREADED           | 8  | 8    | 8     | 11    | 16    | 13    | 15    | 22    | 24    | 25    | 26    |       |       |       |       |       |
|                          |   | L-J<br>STUB<br>END | ANSI                                     | 76   | 76    | 102   | 102   | 152   | 152   | 152   | 203   | 203   | 254   | 254   | 305   | 305   | 305   | 305   |
|                          |   |                    | MSS                                      | 51   | 51    | 51    | 51    | 64    | 64    | 76    | 89    | 102   | 127   | 152   | 152   | 152   | 152   |       |
| BORE: WELD-NECK & SOCKET |   |                    | Order to match Internal Diameter of Pipe |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| BOLTING                  | BOLTS PER FLANGE  |                    | 4  | 4    | 4     | 4     | 8     | 8     | 8     | 12    | 12    | 12    | 16    | 16    | 16    | 16    | 16    | 16    |
|                          | BOLT CIRCLE DIAMETER  |                    | 82.6                                     | 88.9 | 101.6 | 123.8 | 165.1 | 203.2 | 241.3 | 317.5 | 393.7 | 482.6 | 571.5 | 635   | 704.8 | 774.7 | 831.8 | 990.6 |
|                          | DIAMETER OF BOLT (IN)   |                    | 3/4                                      | 3/4  | 7/8   | 1     | 7/8   | 1 1/8 | 1 1/4 | 1 3/8 | 1 5/8 | 1 7/8 | 2     | 2 1/4 | 2 1/2 | 2 3/4 | 3     | 3 1/2 |
|                          | STUDBOLT THREAD<br>length - except<br>lap-joint: Note 5                         | RF                 | 102                                      | 108  | 121   | 133   | 140   | 171   | 190   | 254   | 286   | 337   | 375   | 406   | 444   | 489   | 533   | 610   |
|                          |   | RJ                 | 102                                      | 108  | 121   | 133   | 146   | 178   | 197   | 260   | 298   | 343   | 387   | 425   | 470   | 514   | 565   | 648   |


PN references are discussed under 'FLANGE CLASSES and PRESSURE NUMBERS' - page 233

# CLASS 2500 FLANGE DATA

PN420

- DIMENSIONS INCLUDE 6.4 mm RAISED FACE ON FLANGES (except lap-joint)

TABLE F-6M

| NOMINAL DIAMETER: DN |  |              | 15                                       | 20   | 25    | 40    | 50    | 80    | 100   | 150   | 200   | 250   | 300   |  |  |  |
|----------------------|--|--------------|--|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
| OUTSIDE DIAMETER     |  |              | 133                                      | 140  | 159   | 203   | 235   | 305   | 356   | 483   | 552   | 673   | 762   | <p>ISO STANDARD 2229 IDENTIFIES FLANGES IN CLASSES 150 THRU 2500.</p> <p>DIMENSIONAL DATA ARE SIMILAR TO FLANGES SPECIFIED BY ANSI STANDARD B16.5 EXCEPT FOR BOLT LENGTHS.</p> <p>ANSI B16.5 SPECIFIES LONGER BOLTS. SHORTER BOLTS ARE ACCEPTABLE PROVIDING FULL THREAD ENGAGEMENT IS OBTAINED WHEN FLANGES ARE ASSEMBLED.</p> <p>ISO 2229 SPECIFIES BOLT DIAMETERS IN INCHES.</p> |  |  |
| FLANGE TYPE          | <br>END OF PIPE TO FACE OF FLANGE or LAP JOINT STUB END • | WELD-NECK    | 79                                       | 85   | 95    | 117   | 133   | 174   | 196   | 279   | 324   | 425   | 470   |  |  |  |
|                      |  | SLIP-ON      | Wall thickness of pipe + 2 mm            |      |       |       |       |       |       |       |       |       |       |  |  |  |
|                      |  | SOCKET       | Not available in this class              |      |       |       |       |       |       |       |       |       |       |  |  |  |
|                      |  | THREADED     | 9  | 12   | 8     | 17    | 23    | 13    | 15    | 22    | 24    | 27    | 26    |  |  |  |
|                      |  | L-J STUB END | ANSI                                     | 76   | 76    | 102   | 102   | 152   | 152   | 152   | 203   | 203   | 254   |  |  |  |
|                      |  | MSS          | 51                                       | 51   | 51    | 51    | 64    | 64    | 76    | 89    | 102   | 127   | 152   |  |  |  |
| BORE: WELD-NECK      |  |              | Order to match Internal Diameter of Pipe |      |       |       |       |       |       |       |       |       |       |  |  |  |
| BOLTING              | BOLTS PER FLANGE   |              | 4  | 4    | 4     | 4     | 8     | 8     | 8     | 8     | 12    | 12    | 12    |  |  |  |
|                      | BOLT CIRCLE DIAMETER   |              | 88.9                                     | 95.2 | 107.9 | 146   | 171.4 | 228.6 | 273   | 368.3 | 438.1 | 539.7 | 619.1 |  |  |  |
|                      | DIAMETER OF BOLT (IN)  |              | 3/4                                      | 3/4  | 7/8   | 1 1/8 | 1     | 1 1/4 | 1 1/2 | 2     | 2     | 2 1/2 | 2 3/4 |  |  |  |
|                      | STUDBOLT THREAD length - except lap-joint: Note 5  | RF           | 121                                      | 121  | 133   | 165   | 171   | 216   | 248   | 343   | 381   | 483   | 533   |  |  |  |
|                      |  | RJ           | 121                                      | 121  | 133   | 171   | 178   | 222   | 260   | 356   | 394   | 508   | 559   |  |  |  |

# RING-JOINT GASKET DATA

TABLE F-7M

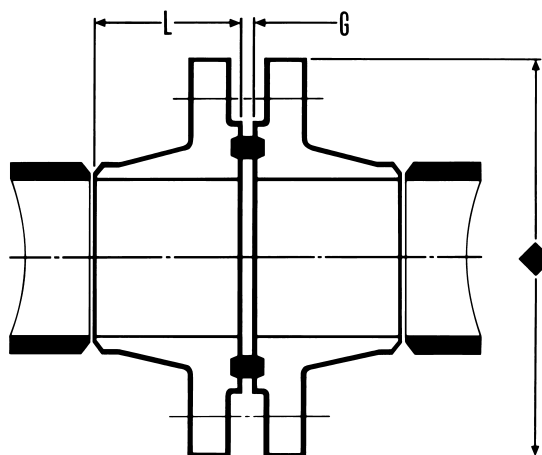
DIMENSIONS IN MILLIMETERS

## DATA FOR WELDING-NECK FLANGES

L = LENGTH THRU HUB OF WELDING-NECK FLANGE WITH RING JOINT

G = GAP BETWEEN FLANGE FACES UNDER NORMAL COMPRESSION

◆ FOR OUTSIDE DIAMETERS OF FLANGES AND BOLTING REFER TO TABLES F-1M THRU F-6M



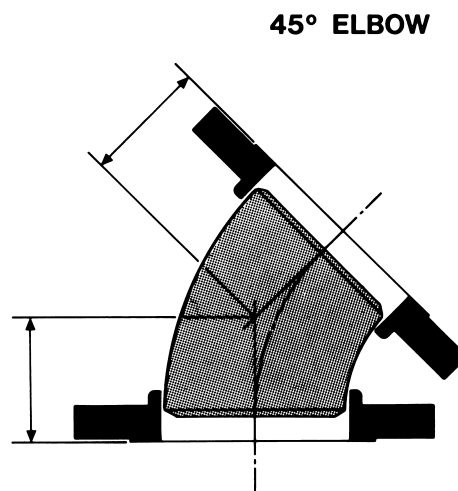
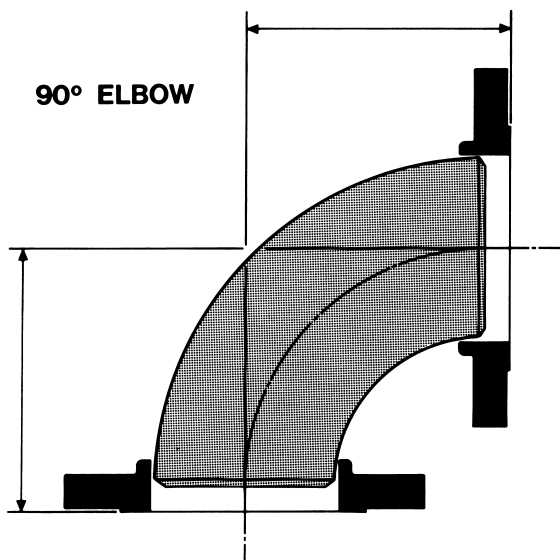
## FLANGE CLASSES

| DN  | 150 |   |         | 300 |     |         | 600 |     |         | 900 |     |         | 1500 |      |         | 2500 |     |         |
|-----|-----|---|---------|-----|-----|---------|-----|-----|---------|-----|-----|---------|------|------|---------|------|-----|---------|
|     | L   | G | RING No | L   | G   | RING No | L   | G   | RING No | L   | G   | RING No | L    | G    | RING No | L    | G   | RING No |
| 15  | -   | - | -       | 58  | 3.2 | R 11    | 58  | 3.2 | R 11    | 66  | 4   | R 12    | 66   | 4    | R 12    | 79   | 4   | R 13    |
| 20  | -   | - | -       | 63  | 4   | R 13    | 63  | 4   | R 13    | 76  | 4   | R 14    | 76   | 4    | R 14    | 85   | 4   | R 16    |
| 25  | 62  | 4 | R 15    | 68  | 4   | R 16    | 68  | 4   | R 16    | 79  | 4   | R 16    | 79   | 4    | R 16    | 95   | 4   | R 18    |
| 40  | 68  | 4 | R 19    | 74  | 4   | R 20    | 76  | 4   | R 20    | 89  | 4   | R 20    | 89   | 4    | R 20    | 119  | 3.2 | R 23    |
| 50  | 70  | 4 | R 22    | 78  | 5.6 | R 23    | 81  | 4.8 | R 23    | 110 | 3.2 | R 24    | 110  | 3.2  | R 24    | 135  | 3.2 | R 26    |
| 80  | 76  | 4 | R 29    | 87  | 5.6 | R 31    | 91  | 4.8 | R 31    | 110 | 4   | R 31    | 125  | 3.2  | R 35    | 178  | 3.2 | R 32    |
| 100 | 82  | 4 | R 36    | 94  | 5.6 | R 37    | 110 | 4.8 | R 37    | 122 | 4   | R 37    | 132  | 3.2  | R 39    | 201  | 4   | R 38    |
| 150 | 95  | 4 | R 43    | 106 | 5.6 | R 45    | 125 | 4.8 | R 45    | 148 | 4   | R 45    | 181  | 3.2  | R 46    | 286  | 4   | R 47    |
| 200 | 108 | 4 | R 48    | 119 | 5.6 | R 49    | 141 | 4.8 | R 49    | 170 | 4   | R 49    | 224  | 4    | R 50    | 332  | 4.8 | R 51    |
| 250 | 108 | 4 | R 52    | 125 | 5.6 | R 53    | 160 | 4.8 | R 53    | 192 | 4   | R 53    | 265  | 4    | R 54    | 437  | 6.3 | R 55    |
| 300 | 120 | 4 | R 56    | 138 | 5.6 | R 57    | 164 | 4.8 | R 57    | 208 | 4   | R 57    | 297  | 4    | R 58    | 482  | 7.9 | R 60    |
| 350 | 133 | 3 | R 59    | 151 | 5.6 | R 61    | 173 | 4.8 | R 61    | 224 | 4   | R 62    | 314  | 5.6  | R 63    |      |     |         |
| 400 | 133 | 3 | R 64    | 154 | 5.6 | R 65    | 186 | 4.8 | R 65    | 227 | 4   | R 66    | 329  | 7.9  | R 67    |      |     |         |
| 450 | 146 | 3 | R 68    | 167 | 5.6 | R 69    | 192 | 4.8 | R 69    | 242 | 4.8 | R 70    | 345  | 7.9  | R 71    |      |     |         |
| 500 | 150 | 3 | R 72    | 172 | 5.6 | R 73    | 200 | 4.8 | R 73    | 261 | 4.8 | R 74    | 374  | 9.5  | R 75    |      |     |         |
| 600 | 158 | 3 | R 76    | 179 | 6.3 | R 77    | 214 | 5.6 | R 77    | 308 | 5.6 | R 78    | 427  | 11.1 | R 79    |      |     |         |

# SLIP-ON FLANGES ON BUTT-WELDING ELBOWS

TABLE F-8M

FOR USE ON BUTT-WELDING ELBOWS AS PERMITTED BY THE PIPING SPECIFICATION FOR THE PROJECT



LR = LONG RADIUS

SR = SHORT RADIUS

\* INDICATES NUMBER OF FLANGES WITHOUT INTERFERENCE

| DN  | CLASS 150 FLANGES |   |       |   |       |   | CLASS 300 FLANGES |   |       |   |       |   |
|-----|-------------------|---|-------|---|-------|---|-------------------|---|-------|---|-------|---|
|     | 90 LR             | * | 90 SR | * | 45 LR | * | 90 LR             | * | 90 SR | * | 45 LR | * |
| 50  | 89                | 1 | 68    | 1 | 48    | 1 | 97                | 1 | 76    | 1 | 56    | 1 |
| 80  | 130               | 2 | 97    | 1 | 67    | 1 | 143               | 1 | 110   | 1 | 79    | 1 |
| 100 | 168               | 2 | 124   | 1 | 79    | 1 | 183               | 2 | 138   | 1 | 94    | 1 |
| 150 | 243               | 2 | 175   | 1 | 110   | 2 | 256               | 2 | 187   | 1 | 122   | 2 |
| 200 | 319               | 2 | 227   | 2 | 141   | 2 | 337               | 2 | 244   | 2 | 159   | 2 |
| 250 | 397               | 2 | 276   | 2 | 175   | 2 | 408               | 2 | 294   | 2 | 186   | 2 |
| 300 | 473               | 2 | 332   | 2 | 206   | 2 | 487               | 2 | 349   | 2 | 221   | 2 |
| 350 | 549               | 2 | 376   | 2 | 238   | 2 | 559               | 2 | 395   | 2 | 248   | 2 |
| 400 | 625               | 2 | 432   | 2 | 270   | 2 | 632               | 2 | 451   | 2 | 276   | 2 |
| 450 | 702               | 2 | 484   | 2 | 302   | 2 | 711               | 2 | 505   | 2 | 311   | 2 |
| 500 | 778               | 2 | 533   | 2 | 333   | 2 | 794               | 2 | 556   | 2 | 349   | 2 |
| 600 | 930               | 2 | 645   | 2 | 395   | 2 | 951               | 2 | 668   | 2 | 418   | 2 |

DIMENSIONS IN MILLIMETERS

# PRESSURE / TEMPERATURE RATINGS FOR CARBON STEEL FLANGES

## TABLE F-9M

Maximum ratings for flanges conforming to ISO Standard 2229 dimensions and material specification ASTM A-105

| TEMPERATURE<br>CELSIUS | GAGE PRESSURE IN kilopascals (kPa) FOR FLANGE CLASSES 150 - 2500 |       |       |       |        |        |        |
|------------------------|--|-------|-------|-------|--------|--------|--------|
|                        | F L A N G E C L A S S E S  |       |       |       |        |        |        |
|                        | 150  | 300   | 400   | 600   | 900    | 1500   | 2500   |
| -29 to 38              | 1 900  | 4 960 | 6 610 | 9 920 | 14 900 | 24 830 | 41 380 |
| 50                     | 1 830  | 4 940 | 6 560 | 9 850 | 14 840 | 24 670 | 41 130 |
| 100                    | 1 630  | 4 800 | 6 400 | 9 600 | 14 450 | 24 020 | 40 060 |
| 150                    | 1 450  | 4 680 | 6 260 | 9 400 | 14 130 | 23 500 | 39 200 |
| 200                    | 1 260  | 4 600 | 6 150 | 9 190 | 13 850 | 23 060 | 38 380 |
| 250                    | 1 070  | 4 370 | 5 850 | 8 780 | 13 170 | 21 920 | 36 600 |
| 300                    | 940  | 3 960 | 5 300 | 7 900 | 11 900 | 19 810 | 33 060 |
| 350                    | 810  | 3 480 | 4 670 | 6 930 | 10 490 | 17 440 | 29 000 |
| 375                    | 750  | 3 210 | 4 340 | 6 380 | 9 660  | 15 800 | 26 770 |
| 400                    | 690  | 2 910 | 3 940 | 5 820 | 8 780  | 14 580 | 24 360 |
| 425                    | 640  | 2 550 | 3 440 | 5 100 | 7 730  | 12 820 | 21 250 |
| 450                    | 580  | 2 140 | 2 880 | 4 270 | 6 460  | 10 760 | 17 820 |
| 475                    | 510  | 1 680 | 2 240 | 3 340 | 5 070  | 8 420  | 14 030 |
| 500                    | 400  | 1 240 | 1 620 | 2 460 | 3 720  | 6 170  | 10 330 |
| 525                    | 340  | 810   | 1 080 | 1 600 | 2 410  | 4 030  | 6 720  |
| 538                    | 260  | 550   | 760   | 1 100 | 1 650  | 2 820  | 4 590  |

ISO 2229 flange dimensions are similar to those of standard ANSI B16.5. Both standards limit the prolonged use of flanges manufactured from carbon steels made to material specification ASTM A-105 at elevated temperatures. ANSI B16.5 also makes recommendations regarding the use of threaded and socket-welding flanges. Refer to footnote: Table F-9.

Ratings are for non-shock conditions. Values in this table do not prevail over limitations imposed by codes, standards, regulations or other obligations which may pertain to projects.

Tables P-1M present calculated data as a guide only. Spans are for pipe arranged in pipeways with the following assumptions: Bare pipe - continuous straight run with welded joints and two or more straight spans at each end.

SPANS - calculated with lines full of water and a maximum bending stress of 4 000 PSI

SAG - (deflection) calculated with lines empty (drained condition)

The following factors were not considered in calculating spans for these tables:

Concentrated mechanical loads from flanges, valves, strainers, filters, and other inline equipment - weights of connecting branch lines - torsional loading from thermal movement - sudden reaction from lines(s) discharging contents - vibration - flattening effect of weight of contents in larger liquid filled lines - weight of insulation and pipe covering - weight of ice and snow - wind loads - seismic shock - reduction in wall thickness of pipe from threading or grooving.

DESIGN PRESSURE - calculated per ANSI B31.1 using allowable stress value of 9 000 PSI for seamless carbon steel pipe

BURSTING PRESSURE is approximate, calculated on yield strength of 30 000 PSI

[E in these tables is for 'Exponent', the power of 10 to which the number must be raised. Example: 1.0E5 = 100 000]

API = American Petroleum Institute's standard 5L, for 'Line pipe'. API pipe sizes; manufacturers' weights: Double-extra-strong (XXS), Extra-strong (XS), and Standard (STD), are included with schedule numbers in standard ANSI B36.10M. Also refer to 2.1.3

## PIPE DATA: DIMENSIONS & STRESS PARAMETERS

## TABLES P-1 M

| DN<br>(mm)<br>[NPS] | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |     |     | DIMENSIONS   |              |              | WEIGHTS         |                       | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(10 <sup>4</sup> mm <sup>4</sup> ) | Section<br>Modulus<br>(10 <sup>3</sup> mm <sup>3</sup> ) | Radius of<br>Gyration<br>(mm) | Continuous Spans |             | Code Pressures  |                   |
|---------------------|---|-----|-----|--------------|--------------|--------------|-----------------|-----------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|-------------------------------|------------------|-------------|-----------------|-------------------|
|                     |   |     |     | O.D.<br>(mm) | I.D.<br>(mm) | Wall<br>(mm) | Empty<br>(kg/m) | Waterfilled<br>(kg/m) | External<br>(mm <sup>2</sup> /mm) | Internal<br>(mm <sup>2</sup> /mm) | Flow<br>(mm <sup>2</sup> ) | Metal<br>(mm <sup>2</sup> ) |  |  |                               | Span<br>(m)      | Sag<br>(mm) | Design<br>(MPa) | Bursting<br>(MPa) |
| 10<br>.375          | SCH 40  | STD | API | 17.15        | 12.52        | 2.311        | .8434           | .9666                 | 53.86                             | 39.34                             | 123.2                      | 107.7                       | 3.035  | .3540  | 5.308                         | 3.52             | 5.42        | 12.1            | 40.3              |
|                     | SCH 80  | XS  | API | 17.15        | 10.74        | 3.200        | 1.098           | 1.188                 | 53.86                             | 33.75                             | 90.66                      | 140.2                       | 3.587  | .4185  | 5.058                         | 3.45             | 5.52        | 19.9            | 66.4              |
| 15<br>.500          | SCH 40  | STD | API | 21.34        | 15.80        | 2.769        | 1.265           | 1.461                 | 67.03                             | 49.63                             | 196.0                      | 161.5                       | 7.114  | .6669  | 6.637                         | 3.93             | 5.39        | 12.6            | 42.1              |
|                     | SCH 80  | XS  | API | 21.34        | 13.87        | 3.734        | 1.617           | 1.768                 | 67.03                             | 43.57                             | 151.1                      | 206.5                       | 8.357  | .7833  | 6.362                         | 3.87             | 5.53        | 19.5            | 64.8              |
|                     | SCH 160                                       |     |     | 21.34        | 11.79        | 4.775        | 1.945           | 2.054                 | 67.03                             | 37.03                             | 109.1                      | 248.4                       | 9.225  | .8648  | 6.094                         | 3.77             | 5.43        | 27.5            | 91.6              |
|                     |   | XXS | API | 21.34        | 6.401        | 7.468        | 2.548           | 2.580                 | 67.03                             | 20.11                             | 32.18                      | 325.4                       | 10.09  | .9458  | 5.569                         | 3.52             | 4.94        | 52.1            | 174               |
| 20<br>.750          | SCH 40  | STD | API | 26.67        | 20.93        | 2.870        | 1.680           | 2.024                 | 83.79                             | 65.75                             | 344.0                      | 214.6                       | 15.42  | 1.156  | 8.475                         | 4.39             | 5.17        | 9.14            | 30.5              |
|                     | SCH 80  | XS  | API | 26.67        | 18.85        | 3.912        | 2.190           | 2.469                 | 83.79                             | 59.21                             | 279.0                      | 279.7                       | 18.64  | 1.398  | 8.164                         | 4.37             | 5.48        | 14.8            | 49.2              |
|                     | SCH 160                                       |     |     | 26.67        | 15.54        | 5.563        | 2.888           | 3.078                 | 83.79                             | 48.84                             | 189.8                      | 368.9                       | 21.97  | 1.647  | 7.717                         | 4.25             | 5.48        | 24.5            | 81.7              |
|                     |   | XXS | API | 26.67        | 11.02        | 7.823        | 3.627           | 3.722                 | 83.79                             | 34.63                             | 95.44                      | 463.2                       | 24.11  | 1.808  | 7.215                         | 4.05             | 5.16        | 39.8            | 133               |
| 25<br>1.00          | SCH 40  | STD | API | 33.40        | 26.64        | 3.378        | 2.495           | 3.052                 | 104.9                             | 83.71                             | 557.6                      | 318.6                       | 36.35  | 2.177  | 10.68                         | 4.91             | 5.08        | 8.77            | 29.2              |
|                     | SCH 80  | XS  | API | 33.40        | 24.31        | 4.547        | 3.227           | 3.691                 | 104.9                             | 76.37                             | 464.1                      | 412.1                       | 43.96  | 2.632  | 10.33                         | 4.91             | 5.43        | 13.8            | 45.9              |
|                     | SCH 160                                       |     |     | 33.40        | 20.70        | 6.350        | 4.225           | 4.562                 | 104.9                             | 65.03                             | 336.6                      | 539.6                       | 52.08  | 3.119  | 9.824                         | 4.80             | 5.51        | 22.1            | 73.7              |
|                     |   | XXS | API | 33.40        | 15.21        | 9.093        | 5.437           | 5.619                 | 104.9                             | 47.80                             | 181.8                      | 694.4                       | 58.46  | 3.501  | 9.176                         | 4.59             | 5.25        | 36.5            | 122               |
| 32<br>1.25          | SCH 40  | STD | API | 42.16        | 35.05        | 3.556        | 3.377           | 4.342                 | 132.5                             | 110.1                             | 965.0                      | 431.3                       | 81.04  | 3.844  | 13.71                         | 5.47             | 4.75        | 7.03            | 23.4              |
|                     | SCH 80  | XS  | API | 42.16        | 32.46        | 4.851        | 4.453           | 5.280                 | 132.5                             | 102.0                             | 827.6                      | 568.7                       | 100.6  | 4.774  | 13.30                         | 5.52             | 5.26        | 11.3            | 37.7              |
|                     | SCH 160                                       |     |     | 42.16        | 29.46        | 6.350        | 5.594           | 6.276                 | 132.5                             | 92.56                             | 681.8                      | 714.5                       | 118.2  | 5.604  | 12.86                         | 5.49             | 5.49        | 16.5            | 55.2              |
|                     |   | XXS | API | 42.16        | 22.76        | 9.703        | 7.748           | 8.155                 | 132.5                             | 71.50                             | 406.8                      | 989.5                       | 142.0  | 6.734  | 11.98                         | 5.28             | 5.41        | 29.5            | 98.5              |
| 40<br>1.50          | SCH 40  | STD | API | 48.26        | 40.89        | 3.683        | 4.039           | 5.352                 | 151.6                             | 128.5                             | 1313                       | 515.8                       | 129.0  | 5.346  | 15.81                         | 5.81             | 4.54        | 6.46            | 21.5              |
|                     | SCH 80  | XS  | API | 48.26        | 38.10        | 5.080        | 5.396           | 6.536                 | 151.6                             | 119.7                             | 1140                       | 689.1                       | 162.8  | 6.748  | 15.37                         | 5.90             | 5.14        | 10.5            | 34.9              |
|                     | SCH 160                                       |     |     | 48.26        | 33.99        | 7.137        | 7.220           | 8.127                 | 151.6                             | 106.8                             | 907.1                      | 922.1                       | 200.8  | 8.321  | 14.76                         | 5.88             | 5.48        | 16.7            | 55.7              |
|                     |   | XXS | API | 48.26        | 27.94        | 10.16        | 9.522           | 10.14                 | 151.6                             | 87.78                             | 613.1                      | 1216                        | 236.4  | 9.795  | 13.94                         | 5.71             | 5.47        | 26.8            | 89.4              |
| 50<br>2.00          | SCH 40  | STD | API | 60.32        | 52.50        | 3.912        | 5.428           | 7.593                 | 189.5                             | 164.9                             | 2165                       | 693.2                       | 277.1  | 9.187  | 19.99                         | 6.39             | 4.17        | 5.07            | 16.9              |
|                     | SCH 80  | XS  | API | 60.32        | 49.25        | 5.537        | 7.463           | 9.368                 | 189.5                             | 154.7                             | 1905                       | 953.1                       | 361.3  | 11.98  | 19.47                         | 6.57             | 4.91        | 8.72            | 29.1              |
|                     |   |     | API | 60.32        | 47.62        | 6.350        | 8.431           | 10.21                 | 189.5                             | 149.6                             | 1781                       | 1077                        | 397.5  | 13.18  | 19.21                         | 6.60             | 5.14        | 10.6            | 35.4              |
|                     | SCH 160                                       |     |     | 60.32        | 42.85        | 8.738        | 11.09           | 12.53                 | 189.5                             | 134.6                             | 1442                       | 1416                        | 484.6  | 16.07  | 18.50                         | 6.58             | 5.47        | 16.4            | 54.7              |
|                     |   | XXS |     | 60.32        | 38.18        | 11.07        | 13.42           | 14.56                 | 189.5                             | 119.9                             | 1145                       | 1713                        | 545.8  | 18.10  | 17.85                         | 6.48             | 5.52        | 22.5            | 75.0              |

Thru DN 250, wall thicknesses for SCH 40S and SCH 80S stainless steel pipes are the same as for SCH 40 and SCH 80 carbon steel pipes  
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# PIPE DATA

# TABLES P-1 M

| DN<br>(mm)<br>[NPS] | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS | DIMENSIONS   |              |              | WEIGHTS         |                       | AREAS                             |                                   |                            | Metal<br>(mm <sup>2</sup> ) | Moment<br>of Inertia<br>(10 <sup>4</sup> mm <sup>4</sup> ) | Section<br>Modulus<br>(10 <sup>3</sup> mm <sup>3</sup> ) | Radius of<br>Gyration<br>(mm) | Continuous Spans |             | Code Pressures  |                   |
|---------------------|---|--------------|--------------|--------------|-----------------|-----------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|-------------------------------|------------------|-------------|-----------------|-------------------|
|                     |   | O.D.<br>(mm) | I.D.<br>(mm) | Wall<br>(mm) | Empty<br>(kg/m) | Waterfilled<br>(kg/m) | External<br>(mm <sup>2</sup> /mm) | Internal<br>(mm <sup>2</sup> /mm) | Flow<br>(mm <sup>2</sup> ) |                             |  |  |                               | Span<br>(m)      | Sag<br>(mm) | Design<br>(MPa) | Bursting<br>(MPa) |
| 65<br>2.50          | SCH 40 STD API                                | 73.03        | 62.71        | 5.156        | 8.608           | 11.70                 | 229.4                             | 197.0                             | 3089                       | 1099                        | 636.6  | 17.44  | 24.06                         | 7.09             | 4.37        | 5.96            | 19.9              |
|                     | SCH 80 XS API                                 | 73.03        | 59.00        | 7.010        | 11.38           | 14.12                 | 229.4                             | 185.4                             | 2734                       | 1454                        | 800.9  | 21.94  | 23.47                         | 7.24             | 4.99        | 9.43            | 31.4              |
|                     | SCH 160                                       | 73.03        | 53.98        | 9.525        | 14.88           | 17.17                 | 229.4                             | 169.6                             | 2288                       | 1900                        | 979.3  | 26.82  | 22.70                         | 7.26             | 5.39        | 14.4            | 48.0              |
|                     | XXS API                                       | 73.03        | 44.98        | 14.02        | 20.35           | 21.94                 | 229.4                             | 141.3                             | 1589                       | 2599                        | 1195   | 32.73  | 21.44                         | 7.10             | 5.51        | 24.0            | 80.1              |
| 80<br>3.00          | API   | 88.90        | 82.55        | 3.175        | 6.695           | 12.05                 | 279.3                             | 259.3                             | 5352                       | 855.1                       | 786.5  | 17.69  | 30.33                         | 7.04             | 2.67        | 1.98            | 6.58              |
|                     | API   | 88.90        | 80.98        | 3.962        | 8.279           | 13.43                 | 279.3                             | 254.4                             | 5150                       | 1057                        | 955.6  | 21.50  | 30.06                         | 7.35             | 3.23        | 3.11            | 10.4              |
|                     | API   | 88.90        | 79.35        | 4.775        | 9.882           | 14.83                 | 279.3                             | 249.3                             | 4945                       | 1262                        | 1120   | 25.20  | 29.79                         | 7.57             | 3.71        | 4.30            | 14.3              |
|                     | SCH 40 STD API                                | 88.90        | 77.93        | 5.486        | 11.26           | 16.03                 | 279.3                             | 244.8                             | 4769                       | 1438                        | 1256   | 28.25  | 29.55                         | 7.71             | 4.05        | 5.36            | 17.9              |
|                     | API   | 88.90        | 76.20        | 6.350        | 12.89           | 17.45                 | 279.3                             | 239.4                             | 4560                       | 1647                        | 1411   | 31.75  | 29.27                         | 7.83             | 4.40        | 6.66            | 22.2              |
|                     | API   | 88.90        | 74.63        | 7.137        | 14.36           | 18.73                 | 279.3                             | 234.4                             | 4374                       | 1833                        | 1544   | 34.73  | 29.02                         | 7.91             | 4.65        | 7.86            | 26.2              |
|                     | SCH 80 XS API                                 | 88.90        | 73.66        | 7.620        | 15.24           | 19.50                 | 279.3                             | 231.4                             | 4261                       | 1946                        | 1621   | 36.47  | 28.86                         | 7.94             | 4.78        | 8.61            | 28.7              |
|                     | SCH 160                                       | 88.90        | 66.65        | 11.13        | 21.28           | 24.77                 | 279.3                             | 209.4                             | 3489                       | 2718                        | 2097   | 47.19  | 27.78                         | 8.02             | 5.36        | 14.2            | 47.5              |
|                     | XXS API                                       | 88.90        | 58.42        | 15.24        | 27.61           | 30.29                 | 279.3                             | 183.5                             | 2680                       | 3527                        | 2494   | 56.11  | 26.59                         | 7.91             | 5.53        | 21.4            | 71.3              |
|                     | API   | 114.3        | 108.0        | 3.175        | 8.679           | 17.83                 | 359.1                             | 339.1                             | 9152                       | 1108                        | 1712   | 29.96  | 39.30                         | 7.53             | 2.08        | .971            | 3.24              |
| 100<br>4            | API   | 114.3        | 106.4        | 3.962        | 10.75           | 19.64                 | 359.1                             | 334.2                             | 8887                       | 1374                        | 2093   | 36.62  | 39.04                         | 7.93             | 2.60        | 1.84            | 6.14              |
|                     | API   | 114.3        | 104.7        | 4.775        | 12.87           | 21.48                 | 359.1                             | 329.1                             | 8618                       | 1643                        | 2468   | 43.19  | 38.76                         | 8.24             | 3.06        | 2.75            | 9.17              |
|                     | API   | 114.3        | 103.2        | 5.563        | 14.88           | 23.24                 | 359.1                             | 324.1                             | 8361                       | 1900                        | 2816   | 49.27  | 38.49                         | 8.46             | 3.45        | 3.64            | 12.1              |
|                     | SCH 40 STD API                                | 114.3        | 102.3        | 6.020        | 16.03           | 24.25                 | 359.1                             | 321.3                             | 8213                       | 2048                        | 3010   | 52.68  | 38.34                         | 8.56             | 3.66        | 4.16            | 13.9              |
|                     | API   | 114.3        | 101.6        | 6.350        | 16.86           | 24.97                 | 359.1                             | 319.2                             | 8107                       | 2154                        | 3148   | 55.08  | 38.23                         | 8.63             | 3.79        | 4.54            | 15.1              |
|                     | API   | 114.3        | 100.0        | 7.137        | 18.81           | 26.67                 | 359.1                             | 314.2                             | 7858                       | 2403                        | 3465   | 60.62  | 37.97                         | 8.76             | 4.08        | 5.45            | 18.2              |
|                     | API   | 114.3        | 98.45        | 7.925        | 20.74           | 28.35                 | 359.1                             | 309.3                             | 7612                       | 2648                        | 3767   | 65.91  | 37.71                         | 8.86             | 4.33        | 6.37            | 21.2              |
|                     | SCH 80 XS API                                 | 114.3        | 97.18        | 8.560        | 22.26           | 29.68                 | 359.1                             | 305.3                             | 7417                       | 2844                        | 4000   | 69.99  | 37.51                         | 8.92             | 4.50        | 7.12            | 23.7              |
|                     | SCH 160                                       | 114.3        | 87.33        | 13.49        | 33.45           | 39.44                 | 359.1                             | 274.3                             | 5989                       | 4272                        | 5524   | 96.65  | 35.96                         | 9.09             | 5.29        | 13.2            | 44.0              |
|                     | XXS API                                       | 114.3        | 80.06        | 17.12        | 40.92           | 45.96                 | 359.1                             | 251.5                             | 5034                       | 5227                        | 6362   | 111.3  | 34.89                         | 9.04             | 5.49        | 18.0            | 59.9              |
|                     | API   | 168.3        | 158.7        | 4.775        | 19.21           | 38.99                 | 528.7                             | 498.6                             | 19787                      | 2453                        | 8203   | 97.50  | 57.83                         | 9.19             | 2.13        | 1.48            | 4.92              |
|                     | API   | 168.3        | 157.1        | 5.563        | 22.26           | 41.66                 | 528.7                             | 493.7                             | 19396                      | 2843                        | 9421   | 112.0  | 57.56                         | 9.52             | 2.48        | 2.07            | 6.90              |
|                     | API   | 168.3        | 155.6        | 6.350        | 25.29           | 44.30                 | 528.7                             | 488.8                             | 19009                      | 3230                        | 10603  | 126.0  | 57.29                         | 9.80             | 2.81        | 2.67            | 8.89              |
|                     | SCH 40 STD API                                | 168.3        | 154.1        | 7.112        | 28.19           | 46.83                 | 528.7                             | 484.0                             | 18639                      | 3601                        | 11714  | 139.2  | 57.04                         | 10.0             | 3.09        | 3.25            | 10.8              |
| 150<br>6            | API   | 168.3        | 152.4        | 7.925        | 31.26           | 49.51                 | 528.7                             | 478.9                             | 18248                      | 3992                        | 12862  | 152.9  | 56.76                         | 10.2             | 3.37        | 3.88            | 12.9              |
|                     | API   | 168.3        | 150.8        | 8.738        | 34.29           | 52.15                 | 528.7                             | 473.8                             | 17860                      | 4379                        | 13975  | 166.1  | 56.49                         | 10.4             | 3.62        | 4.51            | 15.0              |
|                     | SCH 80 XS API                                 | 168.3        | 146.3        | 10.97        | 42.46           | 59.28                 | 528.7                             | 459.7                             | 16817                      | 5423                        | 16853  | 200.3  | 55.75                         | 10.7             | 4.18        | 6.28            | 20.9              |
|                     | SCH 120                                       | 168.3        | 139.7        | 14.27        | 54.08           | 69.41                 | 528.7                             | 439.0                             | 15333                      | 6906                        | 20649  | 245.4  | 54.68                         | 10.9             | 4.76        | 8.96            | 29.9              |
|                     | SCH 160                                       | 168.3        | 131.7        | 18.26        | 67.39           | 81.02                 | 528.7                             | 413.9                             | 13633                      | 8607                        | 24569  | 292.0  | 53.43                         | 11.0             | 5.18        | 12.3            | 41.0              |
|                     | XXS   | 168.3        | 124.4        | 21.95        | 78.99           | 91.14                 | 528.7                             | 390.8                             | 12151                      | 10089                       | 27610  | 328.2  | 52.31                         | 11.0             | 5.39        | 15.5            | 51.8              |
|                     | API   | 219.1        | 209.5        | 4.775        | 25.17           | 59.65                 | 688.2                             | 658.2                             | 34479                      | 3215                        | 18464  | 168.6  | 75.79                         | 9.77             | 1.58        | .985            | 3.28              |
|                     | API   | 219.1        | 208.8        | 5.156        | 27.13           | 61.36                 | 688.2                             | 655.8                             | 34229                      | 3465                        | 19833  | 181.1  | 75.65                         | 9.98             | 1.73        | 1.20            | 4.01              |
|                     | API   | 219.1        | 207.9        | 5.563        | 29.22           | 63.18                 | 688.2                             | 653.3                             | 33963                      | 3731                        | 21277  | 194.2  | 75.51                         | 10.2             | 1.89        | 1.44            | 4.79              |
|                     | SCH 20  | 219.1        | 206.4        | 6.350        | 33.23           | 66.68                 | 688.2                             | 648.3                             | 33451                      | 4244                        | 24026  | 219.3  | 75.24                         | 10.5             | 2.18        | 1.89            | 6.31              |
| 200<br>8            | SCH 30  | 219.1        | 205.0        | 7.036        | 36.70           | 69.71                 | 688.2                             | 644.0                             | 33007                      | 4687                        | 26369  | 240.7  | 75.01                         | 10.8             | 2.41        | 2.29            | 7.64              |
|                     | API   | 219.1        | 203.2        | 7.925        | 41.16           | 73.60                 | 688.2                             | 638.5                             | 32437                      | 5257                        | 29338  | 267.8  | 74.71                         | 11.1             | 2.70        | 2.81            | 9.38              |
|                     | SCH 40 STD API                                | 219.1        | 202.7        | 8.179        | 42.43           | 74.71                 | 688.2                             | 636.9                             | 32275                      | 5419                        | 30172  | 275.5  | 74.62                         | 11.2             | 2.78        | 2.96            | 9.87              |
|                     | API   | 219.1        | 201.6        | 8.738        | 45.21           | 77.13                 | 688.2                             | 633.3                             | 31921                      | 5774                        | 31985  | 292.0  | 74.43                         | 11.3             | 2.95        | 3.29            | 11.0              |
|                     | API   | 219.1        | 200.0        | 9.525        | 49.10           | 80.52                 | 688.2                             | 628.4                             | 31424                      | 6271                        | 34489  | 314.9  | 74.16                         | 11.5             | 3.17        | 3.76            | 12.5              |
|                     | SCH 60  | 219.1        | 198.5        | 10.31        | 52.96           | 83.89                 | 688.2                             | 623.4                             | 30931                      | 6763                        | 36935  | 337.2  | 73.90                         | 11.6             | 3.37        | 4.23            | 14.1              |
|                     | API   | 219.1        | 196.8        | 11.13        | 56.91           | 87.33                 | 688.2                             | 618.3                             | 30426                      | 7268                        | 39399  | 359.7  | 73.63                         | 11.8             | 3.56        | 4.71            | 15.7              |
|                     | SCH 80 XS API                                 | 219.1        | 193.7        | 12.70        | 64.47           | 93.93                 | 688.2                             | 608.4                             | 29460                      | 8234                        | 44002  | 401.7  | 73.10                         | 12.0             | 3.90        | 5.67            | 18.9              |
|                     | SCH 100                                       | 219.1        | 188.9        | 15.09        | 75.71           | 103.7                 | 688.2                             | 593.4                             | 28025                      | 9669                        | 50566  | 461.6  | 72.32                         | 12.3             | 4.31        | 7.13            | 23.8              |
|                     | SCH 120                                       | 219.1        | 182.5        | 18.26        | 90.21           | 116.4                 | 688.2                             | 573.5                             | 26173                      | 11521                       | 58556  | 534.6  | 71.29                         | 12.5             | 4.73        | 9.13            | 30.4              |
|                     | SCH 140                                       | 219.1        | 177.8        | 20.62        | 100.7           | 125.5                 | 688.2                             | 558.7                             | 24836                      | 12859                       | 63984  | 584.1  | 70.54                         | 12.5             | 4.96        | 10.6            | 35.5              |
|                     | XXS API                                       | 219.1        | 174.6        | 22.23        | 107.6           | 131.6                 | 688.2                             | 548.6                             | 23950                      | 13744                       | 67423  | 615.5  | 70.04                         | 12.6             | 5.08        | 11.7            | 38.9              |
|                     | SCH 160                                       | 219.1        | 173.1        | 23.01        | 111.0           | 134.5                 | 688.2                             | 543.7                             | 23520                      | 14174                       | 69048  | 630.4  | 69.79                         | 12.6             | 5.14        | 12.2            | 40.7              |

Thru DN 250, wall thicknesses for SCH 40S and SCH 80S stainless steel pipes are the same as for SCH 40 and SCH 80 carbon steel pipes

# PIPE DATA

# TABLES P-1 M

| TABLE 1. DIMENSIONS AND WEIGHTS OF API 5L X42 AND X60 STEEL PIPE |   |         |              |              |              |                 |                       |                                   |                                   |                            |                             |  |  |                               |                  |             |                 |                   |
|--|---|---------|--------------|--------------|--------------|-----------------|-----------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|-------------------------------|------------------|-------------|-----------------|-------------------|
| DN<br>(mm)<br>[NPS]  | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |         | DIMENSIONS   |              |              | WEIGHTS         |                       | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(10 <sup>4</sup> mm <sup>4</sup> ) | Section<br>Modulus<br>(10 <sup>3</sup> mm <sup>3</sup> ) | Radius of<br>Gyration<br>(mm) | Continuous Spans |             | Code Pressures  |                   |
|  |   |         | O.D.<br>(mm) | I.D.<br>(mm) | Wall<br>(mm) | Empty<br>(kg/m) | Waterfilled<br>(kg/m) | External<br>(mm <sup>2</sup> /mm) | Internal<br>(mm <sup>2</sup> /mm) | Flow<br>(mm <sup>2</sup> ) | Metal<br>(mm <sup>2</sup> ) |  |  |                               | Span<br>(m)      | Sag<br>(mm) | Design<br>(MPa) | Bursting<br>(MPa) |
| 250<br>10  |   | API     | 273.1        | 263.5        | 4.775        | 31.51           | 86.04                 | 857.8                             | 827.8                             | 54532                      | 4025                        | 36218  | 265.3  | 94.86                         | 10.2             | 1.20        | .672            | 2.24              |
|  |   | API     | 273.1        | 262.7        | 5.156        | 33.98           | 88.20                 | 857.8                             | 825.4                             | 54217                      | 4340                        | 38944  | 285.3  | 94.73                         | 10.4             | 1.33        | .847            | 2.82              |
|  |   | API     | 273.1        | 261.9        | 5.563        | 36.60           | 90.48                 | 857.8                             | 822.9                             | 53882                      | 4674                        | 41825  | 306.4  | 94.59                         | 10.7             | 1.46        | 1.03            | 3.45              |
|  | SCH 20  | API     | 273.1        | 260.3        | 6.350        | 41.66           | 94.89                 | 857.8                             | 817.9                             | 53236                      | 5320                        | 47331  | 346.7  | 94.32                         | 11.1             | 1.71        | 1.40            | 4.66              |
|  |   | API     | 273.1        | 258.9        | 7.087        | 46.36           | 99.00                 | 857.8                             | 813.3                             | 52635                      | 5921                        | 52393  | 383.8  | 94.07                         | 11.4             | 1.93        | 1.74            | 5.80              |
|  | SCH 30  | API     | 273.1        | 257.5        | 7.798        | 50.88           | 102.9                 | 857.8                             | 808.8                             | 52058                      | 6498                        | 57198  | 419.0  | 93.82                         | 11.7             | 2.14        | 2.07            | 6.90              |
|  |   | API     | 273.1        | 255.6        | 8.738        | 56.81           | 108.1                 | 857.8                             | 802.9                             | 51301                      | 7255                        | 63428  | 464.6  | 93.50                         | 12.0             | 2.41        | 2.51            | 8.37              |
|  | SCH 40  | STD API | 273.1        | 254.5        | 9.271        | 60.16           | 111.0                 | 857.8                             | 799.6                             | 50874                      | 7683                        | 66903  | 490.0  | 93.32                         | 12.2             | 2.55        | 2.76            | 9.20              |
|  |   | API     | 273.1        | 250.8        | 11.13        | 71.68           | 121.1                 | 857.8                             | 787.9                             | 49402                      | 9154                        | 78647  | 576.1  | 92.69                         | 12.7             | 3.00        | 3.64            | 12.1              |
|  | SCH 60  | XS API  | 273.1        | 247.7        | 12.70        | 81.33           | 129.5                 | 857.8                             | 778.0                             | 48169                      | 10388                       | 88220  | 646.2  | 92.16                         | 13.0             | 3.34        | 4.39            | 14.6              |
|  |   | SCH 80  | 273.1        | 242.9        | 15.09        | 95.74           | 142.1                 | 857.8                             | 763.0                             | 46329                      | 12227                       | 1.0E5  | 747.5  | 91.36                         | 13.3             | 3.78        | 5.55            | 18.5              |
|  | SCH 100                                       | API     | 273.1        | 236.5        | 18.26        | 114.5           | 158.4                 | 857.8                             | 743.1                             | 43938                      | 14618                       | 1.2E5  | 873.3  | 90.31                         | 13.6             | 4.24        | 7.11            | 23.7              |
|  |   | SCH 120 | 273.1        | 230.2        | 21.44        | 132.7           | 174.3                 | 857.8                             | 723.1                             | 41611                      | 16946                       | 1.4E5  | 989.4  | 89.28                         | 13.8             | 4.60        | 8.71            | 29.0              |
|  | SCH 140                                       | XXS API | 273.1        | 222.2        | 25.40        | 154.7           | 193.5                 | 857.8                             | 698.2                             | 38795                      | 19762                       | 1.5E5  | 1121   | 88.02                         | 14.0             | 4.94        | 10.7            | 35.8              |
| SCH 160  |   | 273.1   | 215.9        | 28.58        | 171.8        | 208.5           | 857.8                 | 678.3                             | 36610                             | 21947                      | 1.7E5                       | 1217   | 87.02  | 14.0                          | 5.13             | 12.4        | 41.4            |                   |
| 300<br>12  |   | API     | 323.9        | 313.5        | 5.156        | 40.42           | 117.6                 | 1017                              | 985.0                             | 77209                      | 5162                        | 65558  | 404.9  | 112.7                         | 10.8             | 1.06        | .714            | 2.38              |
|  |   | API     | 323.9        | 312.7        | 5.563        | 43.55           | 120.4                 | 1017                              | 982.5                             | 76809                      | 5562                        | 70458  | 435.1  | 112.5                         | 11.0             | 1.18        | .871            | 2.90              |
|  | SCH 20  | API     | 323.9        | 311.2        | 6.350        | 49.59           | 125.6                 | 1017                              | 977.5                             | 76038                      | 6334                        | 79843  | 493.1  | 112.3                         | 11.5             | 1.39        | 1.18            | 3.92              |
|  |   | API     | 323.9        | 309.6        | 7.137        | 55.61           | 130.9                 | 1017                              | 972.6                             | 75270                      | 7102                        | 89088  | 550.2  | 112.0                         | 11.9             | 1.60        | 1.48            | 4.95              |
|  | SCH 30  | API     | 323.9        | 308.0        | 7.925        | 61.59           | 136.1                 | 1017                              | 967.6                             | 74506                      | 7865                        | 98192  | 606.4  | 111.7                         | 12.3             | 1.81        | 1.79            | 5.97              |
|  |   | API     | 323.9        | 307.1        | 8.382        | 65.05           | 139.1                 | 1017                              | 964.7                             | 74064                      | 8307                        | 1.0E5  | 638.7  | 111.6                         | 12.4             | 1.93        | 1.97            | 6.57              |
|  | STD   | API     | 323.9        | 306.4        | 8.738        | 67.73           | 141.4                 | 1017                              | 962.5                             | 73722                      | 8650                        | 1.1E5  | 663.5  | 111.5                         | 12.6             | 2.02        | 2.11            | 7.04              |
|  |   | API     | 323.9        | 304.8        | 9.525        | 73.65           | 146.6                 | 1017                              | 957.6                             | 72966                      | 9406                        | 1.2E5  | 718.0  | 111.2                         | 12.9             | 2.21        | 2.42            | 8.07              |
|  | SCH 40  | API     | 323.9        | 303.2        | 10.31        | 79.54           | 151.7                 | 1017                              | 952.6                             | 72214                      | 10158                       | 1.2E5  | 771.7  | 110.9                         | 13.1             | 2.39        | 2.73            | 9.11              |
|  |   | API     | 323.9        | 301.6        | 11.13        | 85.58           | 157.0                 | 1017                              | 947.5                             | 71442                      | 10930                       | 1.3E5  | 826.2  | 110.6                         | 13.3             | 2.58        | 3.06            | 10.2              |
|  | XS  | API     | 323.9        | 298.5        | 12.70        | 97.20           | 167.2                 | 1017                              | 937.6                             | 69957                      | 12414                       | 1.5E5  | 929.4  | 110.1                         | 13.7             | 2.90        | 3.69            | 12.3              |
|  |   | API     | 323.9        | 295.3        | 14.27        | 108.7           | 177.2                 | 1017                              | 927.7                             | 68489                      | 13883                       | 1.7E5  | 1029   | 109.6                         | 14.0             | 3.20        | 4.32            | 14.4              |
|  | SCH 60  | API     | 323.9        | 292.1        | 15.88        | 120.3           | 187.3                 | 1017                              | 917.7                             | 67012                      | 15360                       | 1.8E5  | 1128   | 109.0                         | 14.3             | 3.47        | 4.97            | 16.6              |
|  |   | API     | 323.9        | 288.9        | 17.48        | 131.7           | 197.3                 | 1017                              | 907.6                             | 65552                      | 16820                       | 2.0E5  | 1223   | 108.5                         | 14.5             | 3.72        | 5.63            | 18.8              |
|  | SCH 80  | API     | 323.9        | 285.8        | 19.05        | 142.8           | 207.0                 | 1017                              | 897.7                             | 64130                      | 18241                       | 2.1E5  | 1313   | 108.0                         | 14.6             | 3.93        | 6.28            | 20.9              |
|  |   | API     | 323.9        | 281.0        | 21.44        | 159.5           | 221.5                 | 1017                              | 882.7                             | 62005                      | 20367                       | 2.3E5  | 1445   | 107.2                         | 14.8             | 4.22        | 7.28            | 24.3              |
|  | SCH 100                                       | XXS API | 323.9        | 273.1        | 25.40        | 186.5           | 245.0                 | 1017                              | 857.8                             | 58556                      | 23815                       | 2.7E5  | 1649   | 105.9                         | 15.1             | 4.60        | 8.96            | 29.9              |
|  |   | API     | 323.9        | 266.7        | 28.58        | 207.6           | 263.4                 | 1017                              | 837.9                             | 55865                      | 26507                       | 2.9E5  | 1801   | 104.9                         | 15.2             | 4.84        | 10.3            | 34.4              |
| SCH 120  | API   | 323.9   | 257.2        | 33.32        | 238.2        | 290.1           | 1017                  | 808.0                             | 51956                             | 30416                      | 3.3E5                       | 2008   | 103.4  | 15.3                          | 5.10             | 12.4        | 41.4            |                   |
| 350<br>14  |   | API     | 355.6        | 344.9        | 5.334        | 45.96           | 139.4                 | 1117                              | 1084                              | 93445                      | 5870                        | 90034  | 506.4  | 123.9                         | 11.1             | .980        | .712            | 2.37              |
|  |   | API     | 355.6        | 344.5        | 5.563        | 47.90           | 141.1                 | 1117                              | 1082                              | 93198                      | 6117                        | 93711  | 527.1  | 123.8                         | 11.2             | 1.04        | .793            | 2.64              |
|  | SCH 10  | API     | 355.6        | 342.9        | 6.350        | 54.55           | 146.9                 | 1117                              | 1077                              | 92347                      | 6967                        | 1.1E5  | 597.7  | 123.5                         | 11.7             | 1.24        | 1.07            | 3.57              |
|  |   | API     | 355.6        | 341.3        | 7.137        | 61.18           | 152.7                 | 1117                              | 1072                              | 91501                      | 7814                        | 1.2E5  | 667.3  | 123.2                         | 12.1             | 1.43        | 1.35            | 4.50              |
|  | SCH 20  | API     | 355.6        | 339.8        | 7.925        | 67.78           | 158.4                 | 1117                              | 1067                              | 90659                      | 8656                        | 1.3E5  | 736.0  | 123.0                         | 12.5             | 1.63        | 1.63            | 5.43              |
|  |   | API     | 355.6        | 338.1        | 8.738        | 74.55           | 164.3                 | 1117                              | 1062                              | 89793                      | 9521                        | 1.4E5  | 805.9  | 122.7                         | 12.9             | 1.82        | 1.92            | 6.40              |
|  | SCH 30  | STD API | 355.6        | 336.6        | 9.525        | 81.09           | 170.0                 | 1117                              | 1057                              | 88959                      | 10356                       | 1.6E5  | 872.6  | 122.4                         | 13.2             | 2.00        | 2.20            | 7.34              |
|  |   | API     | 355.6        | 333.3        | 11.13        | 94.27           | 181.5                 | 1117                              | 1047                              | 87275                      | 12040                       | 1.8E5  | 1005   | 121.9                         | 13.7             | 2.35        | 2.78            | 9.26              |
|  | SCH 40  | API     | 355.6        | 331.8        | 11.91        | 100.7           | 187.2                 | 1117                              | 1042                              | 86452                      | 12862                       | 1.9E5  | 1069   | 121.6                         | 13.9             | 2.52        | 3.06            | 10.2              |
|  |   | XS API  | 355.6        | 330.2        | 12.70        | 107.1           | 192.8                 | 1117                              | 1037                              | 85634                      | 13681                       | 2.0E5  | 1132   | 121.3                         | 14.1             | 2.67        | 3.35            | 11.2              |
|  | SCH 60  | API     | 355.6        | 325.4        | 15.09        | 126.4           | 209.6                 | 1117                              | 1022                              | 83175                      | 16140                       | 2.3E5  | 1318   | 120.5                         | 14.6             | 3.10        | 4.23            | 14.1              |
|  |   | API     | 355.6        | 323.9        | 15.88        | 132.7           | 215.0                 | 1117                              | 1017                              | 82372                      | 16943                       | 2.4E5  | 1378   | 120.2                         | 14.7             | 3.23        | 4.52            | 15.1              |
|  | SCH 80  | API     | 355.6        | 317.5        | 19.05        | 157.7           | 236.9                 | 1117                              | 997.5                             | 79173                      | 20142                       | 2.9E5  | 1609   | 119.2                         | 15.1             | 3.70        | 5.70            | 19.0              |
|  |   | API     | 355.6        | 307.9        | 23.83        | 194.4           | 268.9                 | 1117                              | 967.5                             | 74482                      | 24833                       | 3.4E5  | 1932   | 117.6                         | 15.6             | 4.25        | 7.51            | 25.0              |
|  | SCH 100                                       | API     | 355.6        | 300.0        | 27.79        | 224.1           | 294.8                 | 1117                              | 942.6                             | 70698                      | 28617                       | 3.9E5  | 2178   | 116.3                         | 15.8             | 4.59        | 9.04            | 30.1              |
|  |   | API     | 355.6        | 292.1        | 31.75        | 252.9           | 319.9                 | 1117                              | 917.7                             | 67012                      | 32303                       | 4.3E5  | 2405   | 115.0                         | 15.9             | 4.86        | 10.6            | 35.4              |
|  | SCH 120                                       | API     | 355.6        | 284.2        | 35.71        | 281.0           | 344.4                 | 1117                              | 892.8                             | 63425                      | 35889                       | 4.6E5  | 2614   | 113.8                         | 16.0             | 5.07        | 12.2            | 40.7              |

Thru DN 250, wall thicknesses for SCH 40S and SCH 80S stainless steel pipes are the same as for SCH 40 and SCH 80 carbon steel pipes  
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# PIPE DATA

# TABLES P-1 M

| DN<br>(mm)<br>[NPS] | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |         | DIMENSIONS   |              |              | WEIGHTS         |                       | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(10 <sup>6</sup> mm <sup>4</sup> ) | Section<br>Modulus<br>(10 <sup>3</sup> mm <sup>3</sup> ) | Radius of<br>Gyration<br>(mm) | Continuous Spans |             | Code Pressures  |                   |
|---------------------|---|---------|--------------|--------------|--------------|-----------------|-----------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|-------------------------------|------------------|-------------|-----------------|-------------------|
|                     |   |         | O.D.<br>(mm) | I.D.<br>(mm) | Wall<br>(mm) | Empty<br>(kg/m) | Waterfilled<br>(kg/m) | External<br>(mm <sup>2</sup> /mm) | Internal<br>(mm <sup>2</sup> /mm) | Flow<br>(mm <sup>2</sup> ) | Metal<br>(mm <sup>2</sup> ) |  |  |                               | Span<br>(m)      | Sag<br>(mm) | Design<br>(MPa) | Bursting<br>(MPa) |
| 400<br>16           | SCH 10  | API     | 406.4        | 395.3        | 5.563        | 54.85           | 177.6                 | 1277                              | 1242                              | 1.2E5                      | 7005                        | 1.4E5  | 692.5  | 141.7                         | 11.5             | .862        | .693            | 2.31              |
|                     |   | API     | 406.4        | 393.7        | 6.350        | 62.49           | 184.2                 | 1277                              | 1237                              | 1.2E5                      | 7981                        | 1.6E5  | 785.9  | 141.5                         | 12.0             | 1.04        | .936            | 3.12              |
|                     |   | API     | 406.4        | 392.1        | 7.137        | 70.10           | 190.9                 | 1277                              | 1232                              | 1.2E5                      | 8953                        | 1.8E5  | 878.2  | 141.2                         | 12.5             | 1.21        | 1.18            | 3.93              |
|                     | SCH 20  | API     | 406.4        | 390.6        | 7.925        | 77.68           | 197.5                 | 1277                              | 1227                              | 1.2E5                      | 9921                        | 2.0E5  | 969.4  | 140.9                         | 12.9             | 1.38        | 1.42            | 4.75              |
|                     |   | API     | 406.4        | 388.9        | 8.738        | 85.47           | 204.3                 | 1277                              | 1222                              | 1.2E5                      | 10916                       | 2.2E5  | 1062   | 140.6                         | 13.2             | 1.56        | 1.68            | 5.59              |
|                     |   | API     | 406.4        | 387.4        | 9.525        | 92.99           | 210.8                 | 1277                              | 1217                              | 1.2E5                      | 11876                       | 2.3E5  | 1151   | 140.4                         | 13.6             | 1.72        | 1.92            | 6.41              |
|                     | SCH 30  | STD API | 406.4        | 384.1        | 11.13        | 108.2           | 224.1                 | 1277                              | 1207                              | 1.2E5                      | 13815                       | 2.7E5  | 1329   | 139.8                         | 14.1             | 2.05        | 2.43            | 8.09              |
|                     |   | API     | 406.4        | 382.6        | 11.91        | 115.6           | 230.6                 | 1277                              | 1202                              | 1.1E5                      | 14764                       | 2.9E5  | 1415   | 139.5                         | 14.4             | 2.20        | 2.67            | 8.92              |
|                     |   | API     | 406.4        | 381.0        | 12.70        | 123.0           | 237.0                 | 1277                              | 1197                              | 1.1E5                      | 15708                       | 3.0E5  | 1499   | 139.3                         | 14.6             | 2.35        | 2.92            | 9.75              |
|                     | SCH 40  | XS API  | 406.4        | 374.7        | 15.88        | 152.5           | 262.7                 | 1277                              | 1177                              | 1.1E5                      | 19477                       | 3.7E5  | 1830   | 138.2                         | 15.3             | 2.89        | 3.94            | 13.1              |
|                     |   | API     | 406.4        | 373.1        | 16.66        | 159.7           | 269.1                 | 1277                              | 1172                              | 1.1E5                      | 20401                       | 3.9E5  | 1910   | 137.9                         | 15.5             | 3.02        | 4.19            | 14.0              |
|                     |   | API     | 406.4        | 368.3        | 19.05        | 181.5           | 288.0                 | 1277                              | 1157                              | 1.1E5                      | 23182                       | 4.4E5  | 2145   | 137.1                         | 15.9             | 3.36        | 4.96            | 16.5              |
|                     | SCH 80  | API     | 406.4        | 363.5        | 21.44        | 203.0           | 306.8                 | 1277                              | 1142                              | 1.0E5                      | 25927                       | 4.8E5  | 2371   | 136.3                         | 16.1             | 3.66        | 5.74            | 19.1              |
|                     | SCH 100                                       | API     | 406.4        | 354.0        | 26.19        | 244.9           | 343.4                 | 1277                              | 1112                              | 98437                      | 31280                       | 5.7E5  | 2795   | 134.7                         | 16.6             | 4.16        | 7.32            | 24.4              |
|                     | SCH 120                                       | API     | 406.4        | 344.5        | 30.96        | 285.9           | 379.1                 | 1277                              | 1082                              | 93198                      | 36520                       | 6.5E5  | 3188   | 133.2                         | 16.8             | 4.54        | 8.93            | 29.8              |
|                     | SCH 140                                       | API     | 406.4        | 333.3        | 36.53        | 332.3           | 419.6                 | 1277                              | 1047                              | 87275                      | 42442                       | 7.3E5  | 3607   | 131.4                         | 17.0             | 4.87        | 10.9            | 36.2              |
|                     | SCH 160                                       | API     | 406.4        | 325.4        | 40.49        | 364.4           | 447.6                 | 1277                              | 1022                              | 83175                      | 46542                       | 7.9E5  | 3880   | 130.2                         | 17.1             | 5.05        | 12.3            | 40.8              |
| 450<br>18           | SCH 10  | API     | 457.2        | 444.5        | 6.350        | 70.42           | 225.6                 | 1436                              | 1396                              | 1.6E5                      | 8994                        | 2.3E5  | 999.9  | 159.4                         | 12.2             | .880        | .832            | 2.77              |
|                     |   | API     | 457.2        | 442.9        | 7.137        | 79.02           | 233.1                 | 1436                              | 1391                              | 1.5E5                      | 10092                       | 2.6E5  | 1118   | 159.1                         | 12.7             | 1.03        | 1.05            | 3.49              |
|                     |   | API     | 457.2        | 441.4        | 7.925        | 87.58           | 240.6                 | 1436                              | 1387                              | 1.5E5                      | 11185                       | 2.8E5  | 1235   | 158.9                         | 13.2             | 1.19        | 1.27            | 4.22              |
|                     | SCH 20  | API     | 457.2        | 439.7        | 8.738        | 96.39           | 248.3                 | 1436                              | 1381                              | 1.5E5                      | 12310                       | 3.1E5  | 1354   | 158.6                         | 13.6             | 1.35        | 1.49            | 4.97              |
|                     |   | STD API | 457.2        | 438.2        | 9.525        | 104.9           | 255.7                 | 1436                              | 1376                              | 1.5E5                      | 13396                       | 3.4E5  | 1469   | 158.3                         | 13.9             | 1.50        | 1.71            | 5.69              |
|                     |   | API     | 457.2        | 436.6        | 10.31        | 113.4           | 263.1                 | 1436                              | 1372                              | 1.5E5                      | 14478                       | 3.6E5  | 1582   | 158.0                         | 14.2             | 1.65        | 1.93            | 6.42              |
|                     | SCH 30  | API     | 457.2        | 434.9        | 11.13        | 122.1           | 270.7                 | 1436                              | 1366                              | 1.5E5                      | 15591                       | 3.9E5  | 1697   | 157.8                         | 14.5             | 1.80        | 2.15            | 7.18              |
|                     |   | API     | 457.2        | 433.4        | 11.91        | 130.5           | 278.0                 | 1436                              | 1361                              | 1.5E5                      | 16665                       | 4.1E5  | 1808   | 157.5                         | 14.8             | 1.94        | 2.37            | 7.91              |
|                     |   | API     | 457.2        | 431.8        | 12.70        | 138.9           | 285.3                 | 1436                              | 1357                              | 1.5E5                      | 17735                       | 4.4E5  | 1918   | 157.2                         | 15.1             | 2.08        | 2.59            | 8.65              |
|                     | SCH 40  | XS API  | 457.2        | 428.7        | 14.27        | 155.5           | 299.8                 | 1436                              | 1347                              | 1.4E5                      | 19863                       | 4.9E5  | 2133   | 156.7                         | 15.5             | 2.35        | 3.04            | 10.1              |
|                     |   | API     | 457.2        | 425.5        | 15.88        | 172.3           | 314.5                 | 1436                              | 1337                              | 1.4E5                      | 22010                       | 5.4E5  | 2347   | 156.1                         | 15.9             | 2.60        | 3.49            | 11.6              |
|                     |   | API     | 457.2        | 419.1        | 19.05        | 205.3           | 343.3                 | 1436                              | 1317                              | 1.4E5                      | 26222                       | 6.3E5  | 2758   | 155.1                         | 16.5             | 3.06        | 4.40            | 14.7              |
|                     | SCH 60  | API     | 457.2        | 409.5        | 23.83        | 254.0           | 385.7                 | 1436                              | 1287                              | 1.3E5                      | 32438                       | 7.6E5  | 3341   | 153.5                         | 17.1             | 3.63        | 5.78            | 19.3              |
|                     | SCH 80  | API     | 457.2        | 398.5        | 29.36        | 309.0           | 433.7                 | 1436                              | 1252                              | 1.2E5                      | 39466                       | 9.1E5  | 3969   | 151.6                         | 17.6             | 4.15        | 7.41            | 24.7              |
|                     | SCH 100                                       | API     | 457.2        | 387.3        | 34.93        | 362.8           | 480.6                 | 1436                              | 1217                              | 1.2E5                      | 46332                       | 1.0E6  | 4548   | 149.8                         | 17.9             | 4.55        | 9.09            | 30.3              |
|                     | SCH 120                                       | API     | 457.2        | 377.9        | 39.67        | 407.5           | 519.6                 | 1436                              | 1187                              | 1.1E5                      | 52041                       | 1.1E6  | 5006   | 148.3                         | 18.0             | 4.81        | 10.5            | 35.1              |
|                     | SCH 140                                       | API     | 457.2        | 366.7        | 45.24        | 458.4           | 564.0                 | 1436                              | 1152                              | 1.1E5                      | 58547                       | 1.3E6  | 5499   | 146.5                         | 18.1             | 5.04        | 12.3            | 40.9              |
| 500<br>20           | SCH 10  | API     | 508.0        | 495.3        | 6.350        | 78.36           | 271.0                 | 1596                              | 1556                              | 1.9E5                      | 10007                       | 3.1E5  | 1240   | 177.4                         | 12.4             | .757        | .748            | 2.49              |
|                     |   | API     | 508.0        | 493.7        | 7.137        | 87.94           | 279.4                 | 1596                              | 1551                              | 1.9E5                      | 11231                       | 3.5E5  | 1387   | 177.1                         | 12.9             | .895        | .943            | 3.14              |
|                     |   | API     | 508.0        | 492.2        | 7.925        | 97.48           | 287.7                 | 1596                              | 1546                              | 1.9E5                      | 12450                       | 3.9E5  | 1533   | 176.8                         | 13.4             | 1.03        | 1.14            | 3.79              |
|                     | SCH 20  | API     | 508.0        | 490.5        | 8.738        | 107.3           | 296.3                 | 1596                              | 1541                              | 1.9E5                      | 13705                       | 4.3E5  | 1682   | 176.5                         | 13.8             | 1.18        | 1.34            | 4.46              |
|                     |   | STD API | 508.0        | 489.0        | 9.525        | 116.8           | 304.6                 | 1596                              | 1536                              | 1.9E5                      | 14916                       | 4.6E5  | 1825   | 176.3                         | 14.2             | 1.32        | 1.54            | 5.12              |
|                     |   | API     | 508.0        | 487.4        | 10.31        | 126.2           | 312.8                 | 1596                              | 1531                              | 1.9E5                      | 16124                       | 5.0E5  | 1966   | 176.0                         | 14.6             | 1.45        | 1.73            | 5.77              |
|                     | SCH 30  | API     | 508.0        | 485.7        | 11.13        | 136.0           | 321.3                 | 1596                              | 1526                              | 1.9E5                      | 17366                       | 5.4E5  | 2111   | 175.7                         | 14.9             | 1.59        | 1.94            | 6.45              |
|                     |   | API     | 508.0        | 484.2        | 11.91        | 145.4           | 329.5                 | 1596                              | 1521                              | 1.8E5                      | 18566                       | 5.7E5  | 2250   | 175.4                         | 15.2             | 1.73        | 2.13            | 7.11              |
|                     |   | API     | 508.0        | 482.6        | 12.70        | 154.7           | 337.7                 | 1596                              | 1516                              | 1.8E5                      | 19762                       | 6.1E5  | 2387   | 175.2                         | 15.4             | 1.86        | 2.33            | 7.77              |
|                     | SCH 40  | XS API  | 508.0        | 477.8        | 15.09        | 182.9           | 362.3                 | 1596                              | 1501                              | 1.8E5                      | 23364                       | 7.1E5  | 2796   | 174.4                         | 16.1             | 2.23        | 2.93            | 9.78              |
|                     |   | API     | 508.0        | 476.3        | 15.88        | 192.2           | 370.3                 | 1596                              | 1496                              | 1.8E5                      | 24544                       | 7.4E5  | 2928   | 174.1                         | 16.3             | 2.35        | 3.13            | 10.4              |
|                     |   | API     | 508.0        | 466.8        | 20.62        | 247.3           | 418.4                 | 1596                              | 1466                              | 1.7E5                      | 31579                       | 9.4E5  | 3698   | 172.5                         | 17.3             | 2.99        | 4.35            | 14.5              |
|                     | SCH 60  | API     | 508.0        | 455.6        | 26.19        | 310.4           | 473.4                 | 1596                              | 1431                              | 1.6E5                      | 39639                       | 1.2E6  | 4542   | 170.6                         | 18.0             | 3.60        | 5.80            | 19.3              |
|                     | SCH 80  | API     | 508.0        | 442.9        | 32.54        | 380.5           | 534.6                 | 1596                              | 1391                              | 1.5E5                      | 48601                       | 1.4E6  | 5432   | 168.5                         | 18.5             | 4.14        | 7.49            | 25.0              |
|                     | SCH 100                                       | API     | 508.0        | 431.8        | 38.10        | 440.4           | 586.8                 | 1596                              | 1357                              | 1.5E5                      | 56245                       | 1.6E6  | 6152   | 166.7                         | 18.8             | 4.51        | 8.99            | 30.0              |
|                     | SCH 120                                       | API     | 508.0        | 419.1        | 44.45        | 506.9           | 644.8                 | 1596                              | 1317                              | 1.4E5                      | 64732                       | 1.8E6  | 6908   | 164.6                         | 19.0             | 4.82        | 10.7            | 35.8              |
|                     | SCH 140                                       | API     | 508.0        | 408.0        | 50.01        | 563.4           | 694.2                 | 1596                              | 1282                              | 1.3E5                      | 71959                       | 1.9E6  | 7516   | 162.9                         | 19.1             | 5.03        | 12.3            | 41.1              |

# PIPE DATA

# TABLES P-1 M

| DN<br>(mm)<br>[NPS] | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |         | DIMENSIONS   |              |              | WEIGHTS         |                       | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(10 <sup>4</sup> mm <sup>4</sup> ) | Section<br>Modulus<br>(10 <sup>3</sup> mm <sup>3</sup> ) | Radius of<br>Gyration<br>(mm) | Continuous Spans |             | Code Pressures  |                   |
|---------------------|---|---------|--------------|--------------|--------------|-----------------|-----------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|-------------------------------|------------------|-------------|-----------------|-------------------|
|                     |   |         | O.D.<br>(mm) | I.D.<br>(mm) | Wall<br>(mm) | Empty<br>(kg/m) | Waterfilled<br>(kg/m) | External<br>(mm <sup>2</sup> /mm) | Internal<br>(mm <sup>2</sup> /mm) | Flow<br>(mm <sup>2</sup> ) | Metal<br>(mm <sup>2</sup> ) |  |  |                               | Span<br>(m)      | Sag<br>(mm) | Design<br>(MPa) | Bursting<br>(MPa) |
| 550<br>22           | SCH 10  | API     | 558.8        | 546.1        | 6.350        | 86.29           | 320.5                 | 1756                              | 1716                              | 2.3E5                      | 11021                       | 4.2E5  | 1505   | 195.3                         | 12.6             | .658        | .680            | 2.27              |
|                     |   | API     | 558.8        | 544.5        | 7.137        | 96.86           | 329.7                 | 1756                              | 1711                              | 2.3E5                      | 12370                       | 4.7E5  | 1684   | 195.1                         | 13.1             | .781        | .857            | 2.86              |
|                     |   | API     | 558.8        | 543.0        | 7.925        | 107.4           | 338.9                 | 1756                              | 1706                              | 2.3E5                      | 13715                       | 5.2E5  | 1862   | 194.8                         | 13.6             | .906        | 1.03            | 3.45              |
|                     | SCH 20  | STD API | 558.8        | 541.3        | 8.738        | 118.2           | 348.4                 | 1756                              | 1701                              | 2.3E5                      | 15099                       | 5.7E5  | 2044   | 194.5                         | 14.1             | 1.04        | 1.22            | 4.06              |
|                     |   | API     | 558.8        | 539.8        | 9.525        | 128.7           | 357.5                 | 1756                              | 1696                              | 2.3E5                      | 16436                       | 6.2E5  | 2219   | 194.2                         | 14.5             | 1.16        | 1.39            | 4.65              |
|                     |   | API     | 558.8        | 538.2        | 10.31        | 139.1           | 366.6                 | 1756                              | 1691                              | 2.3E5                      | 17770                       | 6.7E5  | 2392   | 194.0                         | 14.8             | 1.29        | 1.57            | 5.24              |
|                     | SCH 30  | API     | 558.8        | 536.5        | 11.13        | 149.9           | 376.0                 | 1756                              | 1686                              | 2.3E5                      | 19142                       | 7.2E5  | 2570   | 193.7                         | 15.2             | 1.42        | 1.76            | 5.86              |
|                     |   | API     | 558.8        | 535.0        | 11.91        | 160.3           | 385.0                 | 1756                              | 1681                              | 2.2E5                      | 20467                       | 7.7E5  | 2740   | 193.4                         | 15.5             | 1.54        | 1.94            | 6.45              |
|                     |   | XS API  | 558.8        | 533.4        | 12.70        | 170.6           | 394.1                 | 1756                              | 1676                              | 2.2E5                      | 21788                       | 8.1E5  | 2909   | 193.1                         | 15.8             | 1.66        | 2.12            | 7.05              |
|                     | SCH 60  | API     | 558.8        | 520.7        | 19.05        | 252.9           | 465.9                 | 1756                              | 1636                              | 2.1E5                      | 32303                       | 1.2E6  | 4215   | 190.9                         | 17.5             | 2.56        | 3.58            | 11.9              |
|                     |   | API     | 558.8        | 514.3        | 22.23        | 293.3           | 501.1                 | 1756                              | 1616                              | 2.1E5                      | 37465                       | 1.4E6  | 4834   | 189.9                         | 18.0             | 2.94        | 4.32            | 14.4              |
|                     |   | API     | 558.8        | 501.7        | 28.58        | 372.7           | 570.3                 | 1756                              | 1576                              | 2.0E5                      | 47599                       | 1.7E6  | 6004   | 187.7                         | 18.8             | 3.58        | 5.82            | 19.4              |
|                     | SCH 80  | API     | 558.8        | 489.0        | 34.93        | 450.1           | 637.8                 | 1756                              | 1536                              | 1.9E5                      | 57480                       | 2.0E6  | 7089   | 185.6                         | 19.4             | 4.08        | 7.36            | 24.5              |
|                     |   | API     | 558.8        | 476.3        | 41.27        | 525.4           | 703.6                 | 1756                              | 1496                              | 1.8E5                      | 67107                       | 2.3E6  | 8092   | 183.6                         | 19.7             | 4.47        | 8.92            | 29.7              |
|                     |   | API     | 558.8        | 463.6        | 47.63        | 598.8           | 767.6                 | 1756                              | 1456                              | 1.7E5                      | 76481                       | 2.5E6  | 9018   | 181.5                         | 19.9             | 4.77        | 10.5            | 35.0              |
|                     | SCH 160                                       | API     | 558.8        | 450.9        | 53.98        | 670.3           | 829.9                 | 1756                              | 1416                              | 1.6E5                      | 85602                       | 2.8E6  | 9872   | 179.5                         | 20.0             | 5.00        | 12.1            | 40.4              |
| 600<br>24           | SCH 10  | API     | 609.6        | 596.9        | 6.350        | 94.23           | 374.1                 | 1915                              | 1875                              | 2.8E5                      | 12034                       | 5.5E5  | 1796   | 213.3                         | 12.7             | .577        | .623            | 2.08              |
|                     |   | API     | 609.6        | 595.3        | 7.137        | 105.8           | 384.1                 | 1915                              | 1870                              | 2.8E5                      | 13509                       | 6.1E5  | 2011   | 213.0                         | 13.3             | .688        | .785            | 2.62              |
|                     |   | API     | 609.6        | 593.8        | 7.925        | 117.3           | 394.2                 | 1915                              | 1865                              | 2.8E5                      | 14980                       | 6.8E5  | 2224   | 212.7                         | 13.8             | .801        | .947            | 3.16              |
|                     | SCH 20  | STD API | 609.6        | 592.1        | 8.738        | 129.1           | 404.5                 | 1915                              | 1860                              | 2.8E5                      | 16494                       | 7.4E5  | 2443   | 212.5                         | 14.3             | .920        | 1.11            | 3.72              |
|                     |   | API     | 609.6        | 590.6        | 9.525        | 140.6           | 414.5                 | 1915                              | 1855                              | 2.7E5                      | 17956                       | 8.1E5  | 2652   | 212.2                         | 14.7             | 1.04        | 1.28            | 4.26              |
|                     |   | API     | 609.6        | 589.0        | 10.31        | 152.0           | 424.5                 | 1915                              | 1850                              | 2.7E5                      | 19415                       | 8.7E5  | 2860   | 211.9                         | 15.1             | 1.15        | 1.44            | 4.80              |
|                     | SCH 30  | API     | 609.6        | 587.3        | 11.13        | 163.8           | 434.7                 | 1915                              | 1845                              | 2.7E5                      | 20917                       | 9.4E5  | 3074   | 211.6                         | 15.4             | 1.27        | 1.61            | 5.36              |
|                     |   | API     | 609.6        | 585.8        | 11.91        | 175.1           | 444.6                 | 1915                              | 1840                              | 2.7E5                      | 22368                       | 9.9E5  | 3278   | 211.4                         | 15.8             | 1.39        | 1.77            | 5.91              |
|                     |   | XS API  | 609.6        | 584.2        | 12.70        | 186.5           | 454.5                 | 1915                              | 1835                              | 2.7E5                      | 23815                       | 1.1E6  | 3481   | 211.1                         | 16.1             | 1.50        | 1.94            | 6.46              |
|                     | SCH 40  | API     | 609.6        | 581.1        | 14.27        | 209.0           | 474.2                 | 1915                              | 1825                              | 2.7E5                      | 26698                       | 1.2E6  | 3883   | 210.5                         | 16.6             | 1.72        | 2.27            | 7.56              |
|                     |   | API     | 609.6        | 577.9        | 15.88        | 231.9           | 494.1                 | 1915                              | 1815                              | 2.6E5                      | 29611                       | 1.3E6  | 4284   | 210.0                         | 17.1             | 1.94        | 2.60            | 8.68              |
|                     |   | API     | 609.6        | 574.6        | 17.48        | 254.5           | 513.9                 | 1915                              | 1805                              | 2.6E5                      | 32508                       | 1.4E6  | 4678   | 209.4                         | 17.5             | 2.15        | 2.94            | 9.80              |
|                     | SCH 60  | API     | 609.6        | 571.5        | 19.05        | 276.7           | 533.3                 | 1915                              | 1795                              | 2.6E5                      | 35343                       | 1.5E6  | 5060   | 208.9                         | 17.9             | 2.35        | 3.27            | 10.9              |
|                     |   | API     | 609.6        | 560.4        | 24.61        | 354.2           | 600.8                 | 1915                              | 1760                              | 2.5E5                      | 45233                       | 1.9E6  | 6359   | 207.0                         | 18.9             | 2.98        | 4.46            | 14.9              |
|                     |   | API     | 609.6        | 547.7        | 30.96        | 440.7           | 676.3                 | 1915                              | 1721                              | 2.4E5                      | 56285                       | 2.4E6  | 7751   | 204.9                         | 19.7             | 3.56        | 5.84            | 19.5              |
|                     | SCH 80  | API     | 609.6        | 531.8        | 38.89        | 545.9           | 768.1                 | 1915                              | 1671                              | 2.2E5                      | 69723                       | 2.9E6  | 9357   | 202.2                         | 20.3             | 4.13        | 7.60            | 25.3              |
|                     |   | API     | 609.6        | 517.6        | 46.02        | 638.1           | 848.4                 | 1915                              | 1626                              | 2.1E5                      | 81488                       | 3.3E6  | 10685  | 199.9                         | 20.6             | 4.52        | 9.21            | 30.7              |
|                     |   | API     | 609.6        | 504.9        | 52.37        | 717.9           | 918.1                 | 1915                              | 1586                              | 2.0E5                      | 91686                       | 3.6E6  | 11778  | 197.9                         | 20.8             | 4.79        | 10.7            | 35.6              |
|                     | SCH 160                                       | API     | 609.6        | 490.5        | 59.54        | 805.6           | 994.6                 | 1915                              | 1541                              | 1.9E5                      | 1.0E5                       | 3.9E6  | 12916  | 195.6                         | 20.9             | 5.02        | 12.4            | 41.2              |
| 650<br>26           | SCH 10  | API     | 660.4        | 647.7        | 6.350        | 102.2           | 431.7                 | 2075                              | 2035                              | 3.3E5                      | 13048                       | 7.0E5  | 2113   | 231.3                         | 12.9             | .510        | .575            | 1.92              |
|                     |   | API     | 660.4        | 646.1        | 7.137        | 114.7           | 442.6                 | 2075                              | 2030                              | 3.3E5                      | 14648                       | 7.8E5  | 2367   | 231.0                         | 13.4             | .610        | .724            | 2.41              |
|                     |   | API     | 660.4        | 644.6        | 7.925        | 127.2           | 453.5                 | 2075                              | 2025                              | 3.3E5                      | 16244                       | 8.6E5  | 2618   | 230.7                         | 14.0             | .713        | .874            | 2.91              |
|                     | SCH 20  | STD API | 660.4        | 642.9        | 8.738        | 140.1           | 464.7                 | 2075                              | 2020                              | 3.2E5                      | 17888                       | 9.5E5  | 2876   | 230.4                         | 14.5             | .822        | 1.03            | 3.43              |
|                     |   | API     | 660.4        | 641.4        | 9.525        | 152.5           | 475.6                 | 2075                              | 2015                              | 3.2E5                      | 19477                       | 1.0E6  | 3124   | 230.1                         | 14.9             | .928        | 1.18            | 3.93              |
|                     |   | API     | 660.4        | 639.8        | 10.31        | 164.9           | 486.4                 | 2075                              | 2010                              | 3.2E5                      | 21061                       | 1.1E6  | 3370   | 229.9                         | 15.3             | 1.03        | 1.33            | 4.43              |
|                     | SCH 30  | API     | 660.4        | 638.1        | 11.13        | 177.7           | 497.5                 | 2075                              | 2005                              | 3.2E5                      | 22693                       | 1.2E6  | 3622   | 229.6                         | 15.7             | 1.15        | 1.48            | 4.95              |
|                     |   | API     | 660.4        | 636.6        | 11.91        | 190.0           | 508.3                 | 2075                              | 2000                              | 3.2E5                      | 24269                       | 1.3E6  | 3865   | 229.3                         | 16.0             | 1.25        | 1.64            | 5.45              |
|                     |   | XS API  | 660.4        | 635.0        | 12.70        | 202.3           | 519.0                 | 2075                              | 1995                              | 3.2E5                      | 25842                       | 1.4E6  | 4106   | 229.0                         | 16.3             | 1.36        | 1.79            | 5.95              |
|                     | SCH 40  | API     | 660.4        | 631.9        | 14.27        | 226.9           | 540.4                 | 2075                              | 1985                              | 3.1E5                      | 28976                       | 1.5E6  | 4582   | 228.5                         | 16.9             | 1.57        | 2.09            | 6.97              |
|                     |   | API     | 660.4        | 628.6        | 15.88        | 251.7           | 562.1                 | 2075                              | 1975                              | 3.1E5                      | 32144                       | 1.7E6  | 5058   | 227.9                         | 17.4             | 1.78        | 2.40            | 8.00              |
|                     |   | API     | 660.4        | 622.3        | 19.05        | 300.5           | 604.7                 | 2075                              | 1955                              | 3.0E5                      | 38383                       | 2.0E6  | 5982   | 226.9                         | 18.3             | 2.17        | 3.02            | 10.1              |
|                     | SCH 60  | API     | 711.2        | 698.5        | 6.350        | 110.1           | 493.3                 | 2234                              | 2194                              | 3.8E5                      | 14061                       | 8.7E5  | 2456   | 249.2                         | 13.0             | .455        | .534            | 1.78              |
|                     |   | API     | 711.2        | 696.9        | 7.137        | 123.6           | 505.1                 | 2234                              | 2189                              | 3.8E5                      | 15787                       | 9.8E5  | 2751   | 248.9                         | 13.6             | .545        | .672            | 2.24              |
|                     |   | API     | 711.2        | 695.4        | 7.925        | 137.1           | 516.8                 | 2234                              | 2185                              | 3.8E5                      | 17509                       | 1.1E6  | 3045   | 248.7                         | 14.1             | .639        | .811            | 2.70              |
|                     | SCH 80  | API     | 711.2        | 693.7        | 8.738        | 151.0           | 529.0                 | 2234                              | 2179                              | 3.8E5                      | 19283                       | 1.2E6  | 3345   | 248.4                         | 14.6             | .738        | .954            | 3.18              |
|                     |   | STD API | 711.2        | 692.2        | 9.525        | 164.4           | 540.7                 | 2234                              | 2174                              | 3.8E5                      | 20997                       | 1.3E6  | 3635   | 248.1                         | 15.1             | .836        | 1.09            | 3.65              |

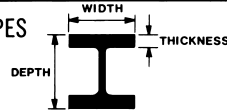
# PIPE DATA

# TABLES P-1 M

| DN<br>(mm)<br>[NPS] | PIPING CODES and<br>MANUFACTURERS'<br>WEIGHTS |         | DIMENSIONS   |              |              | WEIGHTS         |                       | AREAS                             |                                   |                            |                             | Moment<br>of Inertia<br>(10 <sup>8</sup> mm <sup>4</sup> ) | Section<br>Modulus<br>(10 <sup>3</sup> mm <sup>3</sup> ) | Radius of<br>Gyration<br>(mm) | Continuous Spans |             | Code Pressures  |                   |
|---------------------|---|---------|--------------|--------------|--------------|-----------------|-----------------------|-----------------------------------|-----------------------------------|----------------------------|-----------------------------|--|--|-------------------------------|------------------|-------------|-----------------|-------------------|
|                     |   |         | O.D.<br>(mm) | I.D.<br>(mm) | Wall<br>(mm) | Empty<br>(kg/m) | Waterfilled<br>(kg/m) | External<br>(mm <sup>2</sup> /mm) | Internal<br>(mm <sup>2</sup> /mm) | Flow<br>(mm <sup>2</sup> ) | Metal<br>(mm <sup>2</sup> ) |  |  |                               | Span<br>(m)      | Sag<br>(mm) | Design<br>(MPa) | Bursting<br>(MPa) |
|                     | SCH 20 XS<br>SCH 30                           | API     | 711.2        | 690.6        | 10.31        | 177.8           | 552.3                 | 2234                              | 2170                              | 3.7E5                      | 22707                       | 1.4E6  | 3922   | 247.8                         | 15.5             | .935        | 1.23            | 4.11              |
|                     |   | API     | 711.2        | 688.9        | 11.13        | 191.6           | 564.4                 | 2234                              | 2164                              | 3.7E5                      | 24468                       | 1.5E6  | 4216   | 247.5                         | 15.9             | 1.04        | 1.38            | 4.59              |
|                     |   | API     | 711.2        | 687.4        | 11.91        | 204.9           | 576.0                 | 2234                              | 2159                              | 3.7E5                      | 26171                       | 1.6E6  | 4500   | 247.3                         | 16.2             | 1.14        | 1.52            | 5.06              |
|                     |   | API     | 711.2        | 685.8        | 12.70        | 218.2           | 587.6                 | 2234                              | 2155                              | 3.7E5                      | 27869                       | 1.7E6  | 4781   | 247.0                         | 16.6             | 1.24        | 1.66            | 5.52              |
|                     |   | API     | 711.2        | 679.5        | 15.88        | 271.5           | 634.1                 | 2234                              | 2135                              | 3.6E5                      | 34678                       | 2.1E6  | 5897   | 245.9                         | 17.7             | 1.63        | 2.23            | 7.42              |
|                     |   | API     | 711.2        | 673.1        | 19.05        | 324.3           | 680.2                 | 2234                              | 2115                              | 3.6E5                      | 41423                       | 2.5E6  | 6981   | 244.8                         | 18.6             | 2.00        | 2.80            | 9.33              |
| 750<br>30           | SCH 10  | API     | 762.0        | 747.7        | 7.137        | 132.5           | 571.6                 | 2394                              | 2349                              | 4.4E5                      | 16926                       | 1.2E6  | 3165   | 266.9                         | 13.7             | .490        | .627            | 2.09              |
|                     |   | API     | 762.0        | 746.2        | 7.925        | 147.0           | 584.3                 | 2394                              | 2344                              | 4.4E5                      | 18774                       | 1.3E6  | 3503   | 266.6                         | 14.2             | .576        | .757            | 2.52              |
|                     |   | API     | 762.0        | 744.5        | 8.738        | 161.9           | 597.3                 | 2394                              | 2339                              | 4.4E5                      | 20677                       | 1.5E6  | 3850   | 266.3                         | 14.7             | .667        | .890            | 2.97              |
|                     |   | STD API | 762.0        | 743.0        | 9.525        | 176.3           | 609.8                 | 2394                              | 2334                              | 4.3E5                      | 22517                       | 1.6E6  | 4184   | 266.1                         | 15.2             | .757        | 1.02            | 3.40              |
|                     |   | API     | 762.0        | 741.4        | 10.31        | 190.7           | 622.4                 | 2394                              | 2329                              | 4.3E5                      | 24353                       | 1.7E6  | 4515   | 265.8                         | 15.6             | .849        | 1.15            | 3.83              |
|                     |   | API     | 762.0        | 739.7        | 11.13        | 205.5           | 635.3                 | 2394                              | 2324                              | 4.3E5                      | 26244                       | 1.8E6  | 4856   | 265.5                         | 16.1             | .944        | 1.28            | 4.28              |
|                     | SCH 20 XS<br>SCH 30                           | API     | 762.0        | 738.2        | 11.91        | 219.8           | 647.8                 | 2394                              | 2319                              | 4.3E5                      | 28072                       | 2.0E6  | 5183   | 265.2                         | 16.4             | 1.04        | 1.42            | 4.72              |
|                     |   | API     | 762.0        | 736.6        | 12.70        | 234.1           | 660.2                 | 2394                              | 2314                              | 4.3E5                      | 29896                       | 2.1E6  | 5508   | 265.0                         | 16.8             | 1.13        | 1.55            | 5.15              |
|                     |   | API     | 762.0        | 730.3        | 15.88        | 291.4           | 710.2                 | 2394                              | 2294                              | 4.2E5                      | 37211                       | 2.6E6  | 6800   | 263.9                         | 18.0             | 1.50        | 2.08            | 6.92              |
|                     |   | API     | 762.0        | 723.9        | 19.05        | 348.1           | 759.7                 | 2394                              | 2274                              | 4.1E5                      | 44464                       | 3.1E6  | 8057   | 262.8                         | 18.9             | 1.86        | 2.61            | 8.69              |
| 800<br>32           | SCH 10  | API     | 812.8        | 800.1        | 6.350        | 126.0           | 628.7                 | 2553                              | 2514                              | 5.0E5                      | 16088                       | 1.3E6  | 3218   | 285.1                         | 13.1             | .367        | .467            | 1.56              |
|                     |   | API     | 812.8        | 798.5        | 7.137        | 141.5           | 642.3                 | 2553                              | 2509                              | 5.0E5                      | 18065                       | 1.5E6  | 3607   | 284.9                         | 13.8             | .443        | .588            | 1.96              |
|                     |   | API     | 812.8        | 797.0        | 7.925        | 156.9           | 655.7                 | 2553                              | 2504                              | 5.0E5                      | 20039                       | 1.6E6  | 3993   | 284.6                         | 14.3             | .522        | .709            | 2.36              |
|                     |   | API     | 812.8        | 795.3        | 8.738        | 172.8           | 669.6                 | 2553                              | 2499                              | 5.0E5                      | 22072                       | 1.8E6  | 4390   | 284.3                         | 14.9             | .606        | .834            | 2.78              |
|                     |   | STD API | 812.8        | 793.8        | 9.525        | 188.2           | 683.0                 | 2553                              | 2494                              | 4.9E5                      | 24037                       | 1.9E6  | 4771   | 284.0                         | 15.4             | .689        | .956            | 3.19              |
|                     |   | API     | 812.8        | 792.2        | 10.31        | 203.6           | 696.4                 | 2553                              | 2489                              | 4.9E5                      | 25999                       | 2.1E6  | 5151   | 283.7                         | 15.8             | .774        | 1.08            | 3.59              |
|                     | SCH 20 XS<br>SCH 30<br>SCH 40                 | API     | 812.8        | 790.5        | 11.13        | 219.4           | 710.2                 | 2553                              | 2484                              | 4.9E5                      | 28019                       | 2.3E6  | 5540   | 283.5                         | 16.2             | .862        | 1.20            | 4.01              |
|                     |   | API     | 812.8        | 789.0        | 11.91        | 234.7           | 723.6                 | 2553                              | 2479                              | 4.9E5                      | 29973                       | 2.4E6  | 5915   | 283.2                         | 16.6             | .949        | 1.33            | 4.42              |
|                     |   | API     | 812.8        | 787.4        | 12.70        | 250.0           | 736.9                 | 2553                              | 2474                              | 4.9E5                      | 31923                       | 2.6E6  | 6287   | 282.9                         | 17.0             | 1.04        | 1.45            | 4.83              |
|                     |   | API     | 812.8        | 781.1        | 15.88        | 311.2           | 790.3                 | 2553                              | 2454                              | 4.8E5                      | 39745                       | 3.2E6  | 7767   | 281.8                         | 18.2             | 1.39        | 1.94            | 6.48              |
|                     |   | API     | 812.8        | 777.8        | 17.48        | 341.9           | 817.1                 | 2553                              | 2444                              | 4.8E5                      | 43663                       | 3.5E6  | 8499   | 281.3                         | 18.7             | 1.56        | 2.19            | 7.32              |
|                     |   | API     | 812.8        | 774.7        | 19.05        | 372.0           | 843.3                 | 2553                              | 2434                              | 4.7E5                      | 47504                       | 3.7E6  | 9211   | 280.7                         | 19.2             | 1.72        | 2.44            | 8.14              |
|                     | SCH 10  | API     | 863.6        | 850.9        | 6.350        | 133.9           | 702.6                 | 2713                              | 2673                              | 5.7E5                      | 17101                       | 1.6E6  | 3638   | 303.1                         | 13.2             | .333        | .439            | 1.46              |
|                     |   | API     | 863.6        | 849.3        | 7.137        | 150.4           | 716.9                 | 2713                              | 2668                              | 5.7E5                      | 19204                       | 1.8E6  | 4078   | 302.8                         | 13.9             | .402        | .553            | 1.84              |
|                     |   | API     | 863.6        | 847.8        | 7.925        | 166.8           | 731.3                 | 2713                              | 2663                              | 5.6E5                      | 21303                       | 1.9E6  | 4516   | 302.5                         | 14.4             | .475        | .667            | 2.22              |
|                     |   | API     | 863.6        | 846.1        | 8.738        | 183.7           | 746.0                 | 2713                              | 2658                              | 5.6E5                      | 23466                       | 2.1E6  | 4965   | 302.3                         | 15.0             | .552        | .785            | 2.62              |
|                     |   | STD API | 863.6        | 844.6        | 9.525        | 200.1           | 760.3                 | 2713                              | 2653                              | 5.6E5                      | 25557                       | 2.3E6  | 5397   | 302.0                         | 15.5             | .629        | .899            | 3.00              |
|                     |   | API     | 863.6        | 843.0        | 10.31        | 216.5           | 774.6                 | 2713                              | 2648                              | 5.6E5                      | 27644                       | 2.5E6  | 5828   | 301.7                         | 15.9             | .708        | 1.01            | 3.38              |
| 850<br>34           | SCH 10  | API     | 863.6        | 841.3        | 11.13        | 233.3           | 789.3                 | 2713                              | 2643                              | 5.6E5                      | 29795                       | 2.7E6  | 6269   | 301.4                         | 16.4             | .791        | 1.13            | 3.77              |
|                     |   | API     | 863.6        | 839.8        | 11.91        | 249.6           | 803.5                 | 2713                              | 2638                              | 5.5E5                      | 31874                       | 2.9E6  | 6694   | 301.1                         | 16.8             | .872        | 1.25            | 4.16              |
|                     |   | API     | 863.6        | 838.2        | 12.70        | 265.8           | 817.6                 | 2713                              | 2633                              | 5.5E5                      | 33950                       | 3.1E6  | 7117   | 300.9                         | 17.1             | .953        | 1.36            | 4.54              |
|                     |   | API     | 863.6        | 831.9        | 15.88        | 331.0           | 874.5                 | 2713                              | 2613                              | 5.4E5                      | 42278                       | 3.8E6  | 8798   | 299.8                         | 18.4             | 1.28        | 1.83            | 6.09              |
|                     |   | API     | 863.6        | 828.6        | 17.48        | 363.7           | 903.0                 | 2713                              | 2603                              | 5.4E5                      | 46452                       | 4.2E6  | 9631   | 299.2                         | 19.0             | 1.45        | 2.06            | 6.88              |
|                     |   | API     | 863.6        | 825.5        | 19.05        | 395.8           | 931.0                 | 2713                              | 2593                              | 5.4E5                      | 50544                       | 4.5E6  | 10442  | 298.7                         | 19.5             | 1.61        | 2.30            | 7.66              |
|                     | SCH 20 XS<br>SCH 30<br>SCH 40                 | API     | 863.6        | 838.2        | 12.70        | 265.8           | 817.6                 | 2713                              | 2633                              | 5.5E5                      | 33950                       | 3.1E6  | 7117   | 300.9                         | 17.1             | .953        | 1.36            | 4.54              |
|                     |   | API     | 863.6        | 831.9        | 15.88        | 331.0           | 874.5                 | 2713                              | 2613                              | 5.4E5                      | 42278                       | 3.8E6  | 8798   | 299.8                         | 18.4             | 1.28        | 1.83            | 6.09              |
|                     |   | API     | 863.6        | 828.6        | 17.48        | 363.7           | 903.0                 | 2713                              | 2603                              | 5.4E5                      | 46452                       | 4.2E6  | 9631   | 299.2                         | 19.0             | 1.45        | 2.06            | 6.88              |
|                     |   | API     | 863.6        | 825.5        | 19.05        | 395.8           | 931.0                 | 2713                              | 2593                              | 5.4E5                      | 50544                       | 4.5E6  | 10442  | 298.7                         | 19.5             | 1.61        | 2.30            | 7.66              |
| 900<br>36           | SCH 10  | API     | 914.4        | 901.7        | 6.350        | 141.8           | 780.4                 | 2873                              | 2833                              | 6.4E5                      | 18115                       | 1.9E6  | 4084   | 321.1                         | 13.3             | .303        | .415            | 1.38              |
|                     |   | API     | 914.4        | 900.1        | 7.137        | 159.3           | 795.6                 | 2873                              | 2828                              | 6.4E5                      | 20343                       | 2.1E6  | 4578   | 320.8                         | 13.9             | .367        | .522            | 1.74              |
|                     |   | API     | 914.4        | 898.6        | 7.925        | 176.7           | 810.8                 | 2873                              | 2823                              | 6.3E5                      | 22568                       | 2.3E6  | 5070   | 320.5                         | 14.5             | .434        | .630            | 2.10              |
|                     |   | API     | 914.4        | 896.9        | 8.738        | 194.7           | 826.5                 | 2873                              | 2818                              | 6.3E5                      | 24861                       | 2.5E6  | 5576   | 320.2                         | 15.1             | .506        | .741            | 2.47              |
|                     |   | STD API | 914.4        | 895.4        | 9.525        | 212.0           | 841.6                 | 2873                              | 2813                              | 6.3E5                      | 27077                       | 2.8E6  | 6062   | 319.9                         | 15.6             | .577        | .849            | 2.83              |
|                     |   | API     | 914.4        | 893.8        | 10.31        | 229.3           | 856.7                 | 2873                              | 2808                              | 6.3E5                      | 29290                       | 3.0E6  | 6546   | 319.7                         | 16.1             | .651        | .957            | 3.19              |
|                     | SCH 20 XS<br>SCH 30<br>SCH 40                 | API     | 914.4        | 892.1        | 11.13        | 247.2           | 872.3                 | 2873                              | 2803                              | 6.3E5                      | 31570                       | 3.2E6  | 7043   | 319.4                         | 16.5             | .728        | 1.07            | 3.56              |
|                     |   | API     | 914.4        | 890.6        | 11.91        | 264.5           | 887.4                 | 2873                              | 2798                              | 6.2E5                      | 33775                       | 3.4E6  | 7522   | 319.1                         | 16.9             | .804        | 1.18            | 3.93              |
|                     |   | API     | 914.4        | 889.0        | 12.70        | 281.7           | 902.4                 | 2873                              | 2793                              | 6.2E5                      | 35976                       | 3.7E6  | 7999   | 318.8                         | 17.3             | .880        | 1.29            | 4.29              |
|                     |   | API     | 914.4        | 885.9        | 14.27        | 316.1           | 932.4                 | 2873                              | 2783                              | 6.2E5                      | 40367                       | 4.1E6  | 8944   | 318.3                         | 18.0             | 1.03        | 1.50            | 5.01              |
|                     |   | API     | 914.4        | 882.6        | 15.88        | 350.9           | 962.8                 | 2873                              | 2773                              | 6.1E5                      | 44812                       | 4.5E6  | 9895   | 317.7                         | 18.6             | 1.19        | 1.73            | 5.75              |
|                     |   | API     | 914.4        | 876.3        | 19.05        | 419.6           | 1023                  | 2873                              | 2753                              | 6.0E5                      | 53584                       | 5.4E6  | 11750  | 316.6                         | 19.7             | 1.50        | 2.17            | 7.22              |

# STRUCTURAL STEEL

## W SHAPES



# TABLE S-4M

| DESIGNATION<br>NOM. SIZE<br>x lb/ft  | DEPTH | WIDTH | THICK | DESIGNATION<br>NOM. SIZE<br>x lb/ft | DEPTH | WIDTH | THICK | DESIGNATION<br>NOM. SIZE<br>x lb/ft | DEPTH | WIDTH | THICK | DESIGNATION<br>NOM. SIZE<br>x lb/ft | DEPTH | WIDTH | THICK |
|--|-------|-------|-------|-------------------------------------|-------|-------|-------|-------------------------------------|-------|-------|-------|-------------------------------------|-------|-------|-------|
| DIMENSIONS: mm   |       |       |       | DIMENSIONS: mm                      |       |       |       | DIMENSIONS: mm                      |       |       |       | DIMENSIONS: mm                      |       |       |       |
| <b>W 36</b>  |       |       |       | <b>W 21</b>                         |       |       |       | <b>W 14</b>                         |       |       |       | <b>W 12</b>                         |       |       |       |
| W 36 x 300   | 933   | 423   | 42.7  | W 21 x 147                          | 560   | 318   | 29.2  | x 314                               | 437   | 412   | 58.0* | x 36                                | 311   | 167   | 13.7* |
| x 280  | 928   | 422   | 39.9  | x 142                               | 545   | 334   | 27.8* | x 311                               | 435   | 412   | 57.4  | x 35                                | 317   | 167   | 13.2  |
| x 260  | 921   | 420   | 36.6  | x 132                               | 554   | 316   | 26.3  | x 287                               | 427   | 410   | 53.2* | x 31                                | 307   | 166   | 11.8* |
| x 245  | 916   | 419   | 34.3  | x 127                               | 539   | 332   | 25.0* | x 283                               | 425   | 409   | 52.6  | x 30                                | 313   | 166   | 11.2  |
| x 230  | 912   | 418   | 32.0  | x 122                               | 551   | 315   | 24.4  | x 264                               | 419   | 407   | 49.2* | x 27                                | 304   | 165   | 10.2* |
| x 210  | 932   | 309   | 34.5  | x 112                               | 533   | 330   | 22.0* | x 257                               | 416   | 406   | 48.0  | x 26                                | 310   | 165   | 9.7   |
| x 194  | 927   | 308   | 32.0  | x 111                               | 546   | 313   | 22.2  | x 246                               | 413   | 405   | 46.1* | x 22                                | 313   | 102   | 10.8  |
| x 182  | 923   | 307   | 30.0  | x 101                               | 543   | 312   | 20.3  | x 237                               | 409   | 404   | 44.4* | x 19                                | 309   | 102   | 8.9   |
| x 170  | 919   | 306   | 27.9  | x 96                                | 537   | 230   | 23.7* | x 233                               | 407   | 404   | 43.7  | x 16.5                              | 305   | 102   | 6.8*  |
| x 160  | 915   | 305   | 25.9  | x 93                                | 549   | 214   | 23.6  | x 228                               | 406   | 403   | 42.9* | x 16                                | 305   | 101   | 6.7   |
| x 150  | 911   | 304   | 23.9  | x 83                                | 544   | 212   | 21.2  | x 219                               | 403   | 402   | 41.2* | x 14                                | 303   | 101   | 5.7   |
| x 135  | 903   | 304   | 20.1  | x 82                                | 530   | 228   | 20.2* | x 211                               | 399   | 401   | 39.6  | <b>W 10</b>                         |       |       |       |
| <b>W 33</b>  |       |       |       | x 73                                | 539   | 211   | 18.8  | x 202                               | 397   | 400   | 38.2* | W 10 x 112                          | 289   | 265   | 31.7  |
| W 33 x 241   | 868   | 403   | 35.6  | x 68                                | 537   | 210   | 17.4  | x 193                               | 393   | 399   | 36.6  | x 100                               | 282   | 263   | 28.4  |
| x 240  | 851   | 403   | 35.6* | x 62                                | 533   | 209   | 15.6  | x 184                               | 391   | 398   | 35.0* | x 89                                | 276   | 261   | 25.3* |
| x 221  | 862   | 401   | 32.4  | x 57                                | 535   | 166   | 16.5  | x 176                               | 387   | 398   | 33.3  | x 88                                | 275   | 261   | 25.1  |
| x 220  | 845   | 402   | 32.4* | x 55                                | 528   | 209   | 13.3* | x 167                               | 384   | 396   | 31.7* | x 77                                | 269   | 259   | 22.1  |
| x 201  | 855   | 400   | 29.2  | x 50                                | 529   | 166   | 13.6  | x 159                               | 380   | 395   | 30.2  | x 72                                | 267   | 258   | 20.5* |
| x 200  | 838   | 400   | 29.2* | x 49                                | 529   | 166   | 13.5* | x 158                               | 381   | 395   | 30.2* | x 68                                | 264   | 257   | 19.6  |
| x 152  | 851   | 294   | 26.8  | x 44                                | 525   | 165   | 11.4  | x 150                               | 378   | 394   | 28.7* | x 66                                | 264   | 257   | 19.0* |
| x 141  | 846   | 293   | 24.4  | <b>W 18</b>                         |       |       |       | x 145                               | 375   | 394   | 27.7  | x 60                                | 260   | 256   | 17.3  |
| x 130  | 840   | 292   | 21.7  | W 18 x 119                          | 482   | 286   | 26.9  | x 142                               | 375   | 394   | 27.0* | x 54                                | 256   | 255   | 15.6  |
| x 118  | 835   | 292   | 18.8  | x 114                               | 469   | 301   | 25.2* | x 136                               | 375   | 374   | 27.0* | x 49                                | 253   | 254   | 14.2  |
| <b>W 30</b>  |       |       |       | x 106                               | 476   | 284   | 23.9  | x 132                               | 372   | 374   | 26.2  | x 45                                | 257   | 204   | 15.7  |
| W 30 x 211   | 786   | 384   | 33.4  | x 105                               | 465   | 300   | 23.1* | x 127                               | 371   | 373   | 25.3* | x 39                                | 252   | 203   | 13.5  |
| x 210  | 772   | 384   | 33.4* | x 97                                | 472   | 283   | 22.1  | x 120                               | 368   | 373   | 23.9  | x 33                                | 247   | 202   | 11.0  |
| x 191  | 779   | 382   | 30.1  | x 96                                | 461   | 298   | 21.1* | x 119                               | 368   | 372   | 23.8* | x 30                                | 266   | 148   | 13.0  |
| x 190  | 765   | 382   | 30.1* | x 86                                | 467   | 282   | 19.6  | x 111                               | 365   | 371   | 22.2* | x 29                                | 260   | 147   | 12.7* |
| x 173  | 773   | 381   | 27.1  | x 85                                | 465   | 224   | 23.1* | x 109                               | 364   | 371   | 21.8  | x 26                                | 262   | 147   | 11.2  |
| x 172  | 759   | 381   | 27.1* | x 77                                | 461   | 223   | 21.1* | x 103                               | 362   | 370   | 20.7* | x 25                                | 256   | 146   | 10.9* |
| x 132  | 770   | 268   | 25.4  | x 76                                | 463   | 280   | 17.3  | x 99                                | 360   | 370   | 19.8  | x 22                                | 258   | 146   | 9.1   |
| x 124  | 766   | 267   | 23.6  | x 71                                | 469   | 194   | 20.6  | x 95                                | 359   | 369   | 19.0* | x 21                                | 251   | 146   | 8.6*  |
| x 116  | 762   | 267   | 21.6  | x 70                                | 457   | 222   | 19.1* | x 90                                | 356   | 369   | 18.0  | x 19                                | 260   | 102   | 10.0  |
| x 108  | 758   | 266   | 19.3  | x 65                                | 466   | 193   | 19.1  | x 87                                | 356   | 368   | 17.5* | x 17                                | 257   | 102   | 8.4   |
| x 99   | 753   | 265   | 17.0  | x 64                                | 454   | 221   | 17.4* | x 84                                | 360   | 305   | 19.8* | x 15                                | 254   | 102   | 6.9   |
| <b>W 27</b>  |       |       |       | x 60                                | 463   | 192   | 17.7  | x 82                                | 363   | 257   | 21.7  | x 12                                | 251   | 101   | 5.3   |
| W 27 x 178   | 706   | 358   | 30.2  | x 55                                | 460   | 191   | 16.0  | x 78                                | 357   | 305   | 18.2* | x 11.5                              | 251   | 100   | 5.2*  |
| x 177  | 694   | 358   | 30.2* | x 50                                | 457   | 190   | 14.5  | x 74                                | 360   | 256   | 19.9  | <b>W 8</b>                          |       |       |       |
| x 161  | 701   | 356   | 27.4  | x 46                                | 459   | 154   | 15.4  | x 68                                | 357   | 255   | 18.3  | W 8 x 67                            | 229   | 210   | 23.7  |
| x 160  | 688   | 356   | 27.3* | x 45                                | 454   | 190   | 12.7* | x 61                                | 353   | 254   | 16.4  | x 58                                | 222   | 209   | 20.6  |
| x 146  | 695   | 355   | 24.8  | x 40                                | 455   | 153   | 13.3  | x 53                                | 354   | 205   | 16.8  | x 48                                | 216   | 206   | 17.4  |
| x 145  | 683   | 355   | 24.8* | x 35                                | 450   | 152   | 10.8  | x 48                                | 350   | 204   | 15.1  | x 40                                | 210   | 205   | 14.2  |
| x 114  | 693   | 256   | 23.6  | <b>W 16</b>                         |       |       |       | x 43                                | 347   | 203   | 13.5  | x 35                                | 206   | 204   | 12.6  |
| x 102  | 688   | 254   | 21.1  | W 16 x 100                          | 431   | 265   | 25.0  | x 38                                | 358   | 172   | 13.1  | x 31                                | 203   | 203   | 11.0  |
| x 94   | 684   | 254   | 18.9  | x 96                                | 415   | 293   | 22.2* | x 34                                | 355   | 171   | 11.6  | x 28                                | 205   | 166   | 11.8  |
| x 84   | 678   | 253   | 16.3  | x 89                                | 425   | 263   | 22.2  | x 30                                | 352   | 171   | 9.8   | x 24                                | 201   | 165   | 10.2  |
| <b>W 24</b>  |       |       |       | x 88                                | 410   | 292   | 20.2* | x 26                                | 353   | 128   | 10.7  | x 21                                | 210   | 134   | 10.2  |
| W 24 x 162   | 635   | 329   | 31.0  | x 78                                | 415   | 218   | 22.2* | x 22                                | 349   | 127   | 8.5   | x 20                                | 207   | 134   | 9.6*  |
| x 160  | 628   | 358   | 28.8* | x 77                                | 420   | 261   | 19.3  | <b>W 12</b>                         |       |       |       | x 18                                | 207   | 133   | 8.4   |
| x 146  | 628   | 328   | 27.7  | x 71                                | 410   | 217   | 20.2* | W 12 x 336                          | 427   | 340   | 75.1  | x 17                                | 203   | 133   | 7.8*  |
| x 145  | 622   | 357   | 25.9* | x 67                                | 415   | 260   | 16.9  | x 305                               | 415   | 336   | 68.7  | x 15                                | 206   | 102   | 8.0   |
| x 131  | 622   | 327   | 24.4  | x 64                                | 406   | 216   | 18.2* | x 279                               | 403   | 334   | 62.7  | x 13                                | 203   | 102   | 6.5   |
| x 130  | 616   | 356   | 22.9* | x 58                                | 403   | 215   | 16.4* | x 252                               | 391   | 330   | 57.2  | x 10                                | 200   | 100   | 5.2   |
| x 120  | 617   | 307   | 23.6* | x 57                                | 417   | 181   | 18.2  | x 230                               | 382   | 328   | 52.6  | <b>W 6</b>                          |       |       |       |
| x 117  | 616   | 325   | 21.6  | x 50                                | 413   | 180   | 16.0  | x 210                               | 374   | 325   | 48.3  | W 6 x 25                            | 162   | 154   | 11.6  |
| x 110  | 614   | 306   | 21.7* | x 45                                | 410   | 179   | 14.4  | x 190                               | 365   | 322   | 44.1  | x 20                                | 157   | 153   | 9.3   |
| x 104  | 611   | 324   | 19.1  | x 40                                | 407   | 178   | 12.8  | x 170                               | 356   | 319   | 39.6  | x 16                                | 160   | 102   | 10.3  |
| x 100  | 610   | 305   | 19.7* | x 36                                | 403   | 177   | 10.9  | x 161                               | 353   | 318   | 37.7* | x 15.5                              | 152   | 152   | 6.8*  |
| x 94   | 617   | 230   | 22.2  | x 31                                | 403   | 140   | 11.2  | x 152                               | 348   | 317   | 35.6  | x 15                                | 152   | 152   | 6.6   |
| x 84   | 612   | 229   | 19.6  | x 26                                | 399   | 140   | 8.8   | x 136                               | 341   | 315   | 31.7  | x 12                                | 153   | 102   | 7.1   |
| x 76   | 608   | 228   | 17.3  | <b>W 14</b>                         |       |       |       | x 133                               | 340   | 314   | 31.4* | x 9                                 | 150   | 100   | 5.5   |
| x 68   | 603   | 228   | 14.9  | W 14 x 730                          | 569   | 454   | 124.7 | x 120                               | 333   | 313   | 28.1  | x 8.5                               | 148   | 100   | 4.9*  |
| x 62   | 603   | 179   | 15.0  | x 665                               | 550   | 448   | 114.8 | x 106                               | 327   | 310   | 25.1  | <b>W 5</b>                          |       |       |       |
| x 61   | 602   | 178   | 15.0* | x 605                               | 531   | 442   | 105.7 | x 99                                | 324   | 310   | 23.4* | W 5 x 19                            | 131   | 128   | 10.9  |
| x 55   | 599   | 178   | 12.8  | x 550                               | 514   | 437   | 97.0  | x 96                                | 323   | 309   | 22.9  | x 18.5                              | 130   | 128   | 10.7* |
| <b>* INDICATES A DIMENSIONAL CHANGE<br/>OR SHAPE WAS DISCONTINUED (1978)</b> |       |       |       | x 455                               | 483   | 428   | 81.5  | x 92                                | 321   | 309   | 21.7* | x 16                                | 127   | 127   | 9.1   |
|  |       |       |       | x 426                               | 474   | 424   | 77.1  | x 87                                | 318   | 308   | 20.6  | <b>W 4</b>                          |       |       |       |
|  |       |       |       | x 398                               | 465   | 421   | 72.3  | x 79                                | 314   | 307   | 18.7  | W 4 x 13                            | 106   | 103   | 8.8   |
|  |       |       |       | x 370                               | 455   | 418   | 67.6  | x 72                                | 311   | 306   | 17.0  |                                     |       |       |       |
|  |       |       |       | x 342                               | 446   | 416   | 62.7  | x 65                                | 308   | 305   | 15.4  |                                     |       |       |       |
|  |       |       |       | x 320                               | 427   | 424   | 53.2* | x 58                                | 310   | 254   | 16.3  |                                     |       |       |       |
|  |       |       |       |                                     |       |       |       | x 53                                | 306   | 254   | 14.6  |                                     |       |       |       |
|  |       |       |       |                                     |       |       |       | x 50                                | 310   | 205   | 16.3  |                                     |       |       |       |
|  |       |       |       |                                     |       |       |       | x 45                                | 306   | 204   | 14.6  |                                     |       |       |       |
|  |       |       |       |                                     |       |       |       | x 40                                | 303   | 203   | 13.1  |                                     |       |       |       |

References: ● The Rolling Program for American Wide Flange Structural Shapes - Arbed S.A., Luxembourg  
 ● The Rolling Schedule for Wide Flange Shapes - Nippon Steel Corporation, Japan  
 ● The American Institute of Steel Construction

## CHANNEL DATA

AMERICAN STANDARD

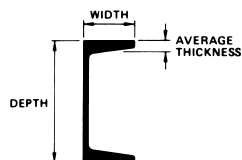
## ANGLE DATA

WEIGHTS IN KILOGRAMS PER LINEAR METER

## TABLES S-5M

| DESIGNATION<br>Depth (ins)<br>x wgt lb/ft | DIMENSIONS IN mm |    |      |
|---|------------------|----|------|
|   | DEPTH:WIDTH:Av   | Th |      |
| C 15x50<br>x40<br>x33.9                   | 381              | 94 | 16.5 |
|   | 381              | 89 | 16.5 |
|   | 381              | 86 | 16.5 |
| C 12x30<br>x25<br>x20.7                   | 305              | 81 | 12.7 |
|   | 305              | 77 | 12.7 |
|   | 305              | 75 | 12.7 |
| C 10x30<br>x25<br>x20<br>x15.3            | 254              | 77 | 11.1 |
|   | 254              | 73 | 11.1 |
|   | 254              | 70 | 11.1 |
|   | 254              | 66 | 11.1 |
| C 9x20<br>x15<br>x13.4                    | 229              | 67 | 10.5 |
|   | 229              | 63 | 10.5 |
|   | 229              | 62 | 10.5 |
| C 8x18.75<br>x13.75<br>x11.5              | 203              | 64 | 9.9  |
|   | 203              | 60 | 9.9  |
|   | 203              | 57 | 9.9  |
| C 7x14.75<br>x12.25<br>x 9.8              | 178              | 58 | 9.3  |
|   | 178              | 56 | 9.3  |
|   | 178              | 53 | 9.3  |
| C 6x13<br>x10.5<br>x 8.2                  | 152              | 55 | 8.7  |
|   | 152              | 52 | 8.7  |
|   | 152              | 49 | 8.7  |
| C 5x 9<br>x 6.7                           | 127              | 48 | 8.1  |
|   | 127              | 48 | 8.1  |
| C 4x 7.25<br>x 5.4                        | 120              | 44 | 7.5  |
|   | 120              | 40 | 7.5  |
| C 3x 6<br>x 5<br>x 4.1                    | 76               | 41 | 6.9  |
|   | 76               | 38 | 6.9  |
|   | 76               | 36 | 6.9  |

AMERICAN STANDARD CHANNELS



### UNEQUAL LEGS

| SIZES & THICKNESSES |             | 1    | 7/8  | 3/4  | 5/8  | 9/16 | 1/2  | 7/16 | 3/8  | 5/16 | 1/4  | 3/16 | 1/8 |
|---------------------|-------------|------|------|------|------|------|------|------|------|------|------|------|-----|
| INCHES              | MILLIMETERS | 25.4 | 22.2 | 19   | 15.9 | 14.3 | 12.7 | 11.1 | 9.5  | 7.5  | 6.4  | 4.8  | 3.2 |
| 9 x 4 x             | 229 x 102 x |      |      |      | 39.1 | 35.4 | 31.7 |      |      |      |      |      |     |
| 8 x 6 x             | 203 x 152 x | 65.8 | 58.2 | 50.3 | 42.4 | 38.2 | 34.2 | 30.1 |      |      |      |      |     |
| 8 x 4 x             | 203 x 102 x | 55.6 |      | 42.7 |      | 32.6 | 29.2 |      |      |      |      |      |     |
| 7 x 4 x             | 178 x 102 x |      |      | 39   | 32.9 |      | 26.6 |      | 20.2 |      |      |      |     |
| 6 x 4               | 152 x 102 x |      | 40.5 | 35.1 | 29.8 | 26.9 | 24.1 | 21.3 | 18.3 | 15.3 |      |      |     |
| 6 x 3 1/2 x         | 152 x 89 x  |      |      |      |      |      | 22.8 |      | 17.4 | 14.6 |      |      |     |
| 5 x 3 1/2 x         | 127 x 89 x  |      |      | 29.5 | 25   |      | 20.2 | 17.9 | 15.5 | 12.9 | 10.4 |      |     |
| 5 x 3 x             | 127 x 76 x  |      |      |      | 23.4 |      | 19   | 16.8 | 14.6 | 12.2 | 9.8  |      |     |
| 4 x 3 1/2 x         | 102 x 89 x  |      |      |      | 21.9 |      | 17.7 | 15.8 | 13.5 | 11.5 | 9.2  |      |     |
| 4 x 3 x             | 102 x 76 x  |      |      |      | 20.2 |      | 16.5 | 14.6 | 12.6 | 10.7 | 8.6  |      |     |
| 3 1/2 x 3 x         | 89 x 76 x   |      |      |      |      |      | 15.2 | 13.5 | 11.8 | 9.8  | 8    |      |     |
| 3 1/2 x 2 1/2 x     | 89 x 64 x   |      |      |      |      |      | 14   | 12.4 | 10.7 | 9.1  | 7.3  |      |     |
| 3 x 2 1/2 x         | 76 x 64 x   |      |      |      |      |      | 12.6 | 11.3 | 9.8  | 8.3  | 6.7  | 5    |     |
| 3 x 2 x             | 76 x 51 x   |      |      |      |      |      | 11.5 | 10.1 | 8.8  | 7.4  | 6.1  | 4.6  |     |
| 2 1/2 x 2 x         | 64 x 51 x   |      |      |      |      |      |      |      | 7.9  | 6.7  | 5.4  | 4.1  |     |
| *2 1/2 x 1 1/2 x    | 64 x 38 x   |      |      |      |      |      |      |      |      | 5.8  | 4.7  | 3.6  |     |
| *2 x 1 1/2 x        | 51 x 38 x   |      |      |      |      |      |      |      |      |      | 4.1  | 3.2  | 2.1 |
| *2 x 1 1/4 x        | 51 x 32 x   |      |      |      |      |      |      |      |      |      | 3.8  | 2.9  |     |
| *1 3/4 x 1 1/4 x    | 44 x 32 x   |      |      |      |      |      |      |      |      |      | 3.5  | 2.7  | 1.8 |

### EQUAL LEGS

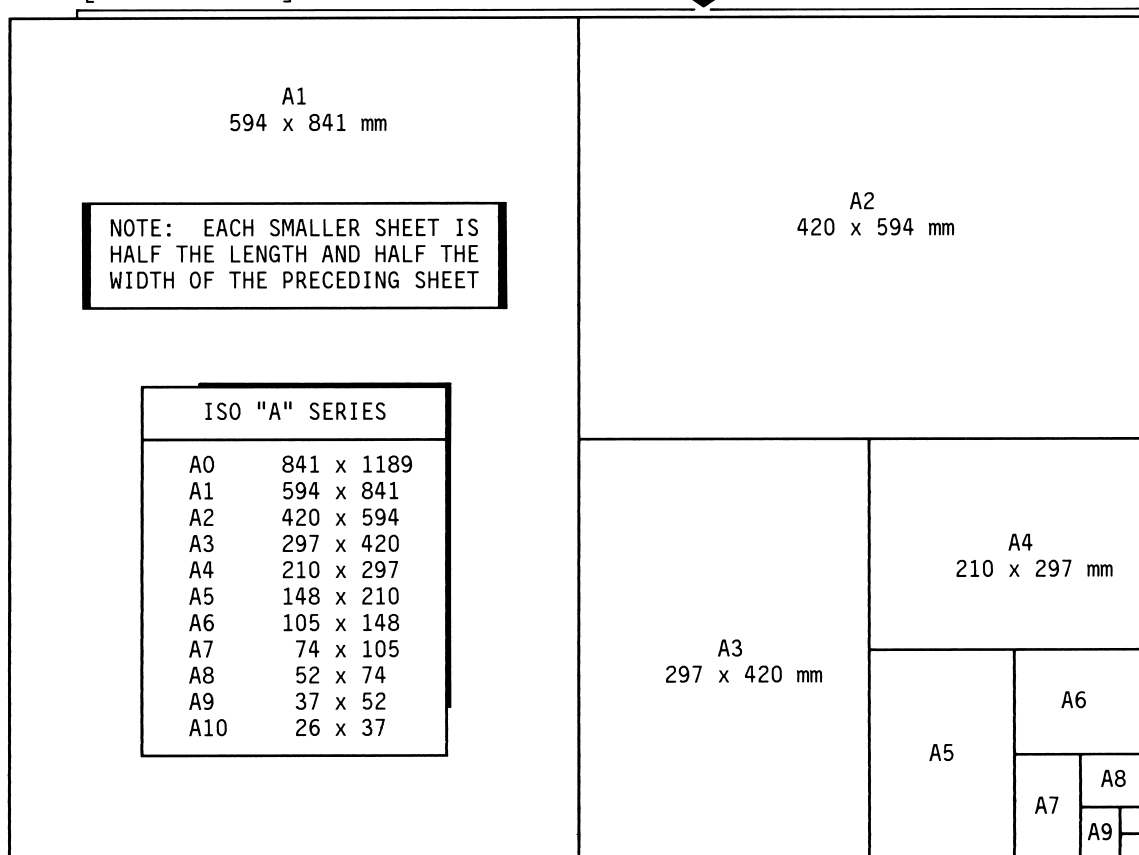
| SIZES & THICKNESSES |             | 1 1/8 | 1    | 7/8  | 3/4  | 5/8  | 9/16 | 1/2  | 7/16 | 3/8  | 5/16 | 1/4 | 3/16 | 1/8 |
|---------------------|-------------|-------|------|------|------|------|------|------|------|------|------|-----|------|-----|
| INCHES              | MILLIMETERS | 28.6  | 25.4 | 22.2 | 19   | 15.9 | 14.3 | 12.7 | 11.1 | 9.5  | 7.9  | 6.4 | 4.8  | 3.2 |
| 8 x 8 x             | 203 x 203 x | 84.7  | 75.9 | 67   | 57.9 | 48.7 | 44   | 39.3 |      |      |      |     |      |     |
| 6 x 6 x             | 152 x 152 x |       | 55.7 | 49.3 | 42.7 | 36   | 32.6 | 29.2 | 25.6 | 22.2 | 18.5 |     |      |     |
| 5 x 5 x             | 127 x 127 x |       |      | 40.5 | 35.1 | 29.8 |      | 24.1 | 21.3 | 18.3 | 15.3 |     |      |     |
| 4 x 4 x             | 102 x 102 x |       |      |      | 27.5 | 23.4 |      | 19   | 16.8 | 14.6 | 12.2 | 9.8 |      |     |
| 3 1/2 x 3 1/2 x     | 89 x 89 x   |       |      |      |      |      |      | 16.5 | 14.6 | 12.6 | 10.7 | 8.6 |      |     |
| 3 x 3 x             | 76 x 76 x   |       |      |      |      |      |      | 14   | 12.4 | 10.7 | 9.1  | 7.3 | 5.5  |     |
| 2 1/2 x 2 1/2 x     | 64 x 64 x   |       |      |      |      |      |      | 11.5 |      | 8.8  | 7.4  | 6.1 | 4.6  |     |
| 2 x 2 x             | 51 x 51 x   |       |      |      |      |      |      |      |      | 7    | 5.8  | 4.7 | 3.6  | 2.5 |
| *1 3/4 x 1 3/4 x    | 44 x 44 x   |       |      |      |      |      |      |      |      |      |      | 4.1 | 3.2  | 2.1 |
| *1 1/2 x 1 1/2 x    | 38 x 38 x   |       |      |      |      |      |      |      |      | 5    |      | 3.5 | 2.7  | 1.8 |
| *1 1/4 x 1 1/4 x    | 32 x 32 x   |       |      |      |      |      |      |      |      |      |      | 2.9 | 2.2  | 1.5 |
| *1 x 1 x            | 25 x 25 x   |       |      |      |      |      |      |      |      |      |      | 2.2 | 1.7  | 1.2 |

# SIZES OF METRIC PAPERS

# CHART S-6M

THE MOST COMMON SIZES OF PAPERS FOR GENERAL USE ARE THE ISO "A" SERIES DESIGNATED: A0, A1, A2, A3, ETC., WITH LENGTH TO WIDTH RATIO OF: LENGTH = WIDTH x SQUARE ROOT 2 (1.414). THE AREA OF THE LARGEST SHEET, A0, IS EQUAL TO ONE SQUARE METER

[REPRESENTATIVE] SHEET SIZE A0: 841 x 1189 mm



COMPARISON OF ISO SHEET SIZES WITH USA SHEET SIZES, FOR DRAWINGS

| ISO<br>DESIGNATION | WIDTH |        | LENGTH |        | US SIZES |             |
|--------------------|-------|--------|--------|--------|----------|-------------|
|                    | mm    | inches | mm     | inches | LETTER   | inches      |
| --                 | --    | --     | --     | --     | F        | 28.0 x 40.0 |
| A0                 | 841   | 33.11  | 1189   | 46.81  | E        | 34.0 x 44.0 |
| A1                 | 594   | 23.39  | 841    | 33.11  | D        | 22.0 x 34.0 |
| A2                 | 420   | 16.54  | 594    | 23.39  | C        | 17.0 x 22.0 |
| A3                 | 297   | 11.69  | 420    | 16.54  | B        | 11.0 x 17.0 |
| A4                 | 210   | 8.27   | 297    | 11.69  | A        | 8.5 x 11.0  |

# VALVE DATA - RUN LENGTHS

DIMENSIONS IN MILLIMETERS

## TABLE V-1M

| FLANGE CLASS   |             | NOMINAL DIAMETER [DN] OF PIPE |     |     |     |     |      |      |      |  |      |      |      |      |
|--|-------------|-------------------------------|-----|-----|-----|-----|------|------|------|--|------|------|------|------|
|  |             | 50                            | 65  | 80  | 100 | 150 | 200  | 250  | 300  | 350  | 400  | 450  | 500  | 600  |
| STEEL GATE VALVES<br>SOLID WEDGE & DOUBLE DISC (SPLIT-WEDGE) | FLANGED 150 | 178                           | 190 | 203 | 229 | 267 | 292  | 330  | 356  | 381  | 406  | 432  | 457  | 508  |
|  | BEVELED 150 | 216                           | 241 | 283 | 305 | 403 | 419  | 457  | 502  | 572  | 610  | 660  | 711  | 813  |
|  | 300         | 216                           | 241 | 283 | 305 | 403 | 419  | 457  | 502  | 762  | 838  | 914  | 991  | 1143 |
|  | 600         | 292                           | 330 | 356 | 432 | 559 | 660  | 787  | 838  | 889  | 991  | 1092 | 1194 | 1397 |
|  | 900         | 368                           | 419 | 381 | 457 | 610 | 737  | 838  | 965  | 1029   | 1130 | 1219 | 1321 | 1549 |
|  | 1500        | 368                           | 419 | 470 | 546 | 705 | 832  | 991  | 1130 | 1257   | 1384 | 1537 | 1664 | 1943 |
|  | 2500        | 451                           | 508 | 578 | 673 | 914 | 1022 | 1270 | 1422 | <b>NOTES</b><br><br>DIMENSIONS IN THIS TABLE CONFORM TO ANSI B16.10 AND APPLY TO FLANGED VALVES AND VALVES WITH ENDS BEVELLED FOR WELDING AS SHOWN:<br><br>Tabled Dimension<br><br>FOR FLANGED VALVES THE TABLED DIMENSION INCLUDES ALLOWANCE FOR BOTH RAISED FACES OF THE VALVE. FOR CLASSES 150 AND 300 VALVES, 1.6mm HAS BEEN INCLUDED FOR EACH RAISED FACE AND FOR VALVES OF CLASS 600 AND ABOVE, 6.4mm HAS BEEN INCLUDED FOR EACH RAISED FACE.<br><br>Half Tabled Dimension<br><br>FOR ANGLE GLOBE & ANGLE LIFT-CHECK VALVES, HALVE THE TABLED DIMENSION TO OBTAIN CENTER-TO-FACE DIMENSIONS. |      |      |      |      |
| STEEL GLOBE VALVES<br>LIFT CHECK VALVES                      | 150         | 203                           | 216 | 241 | 292 | 406 | 495  | 622  | 698  |  |      |      |      |      |
|  | 300         | 267                           | 292 | 318 | 356 | 444 | 559  | 622  | 711  |  |      |      |      |      |
|  | 600         | 292                           | 330 | 356 | 432 | 559 | 660  | 787  | 838  |  |      |      |      |      |
|  | 900         | 368                           | 419 | 381 | 457 | 610 | 737  | 838  | 965  |  |      |      |      |      |
|  | 1500        | 368                           | 419 | 470 | 546 | 705 | 832  | 991  | 1130 |  |      |      |      |      |
|  | 2500        | 451                           | 508 | 578 | 673 | 914 | 1022 | 1270 | 1422 |  |      |      |      |      |
| SWING CHECK VALVES<br>TILTING DISC CHECK VALVES              | T-D 150     | 203                           | 216 | 241 | 292 | 356 | 495  | 622  | 698  |  |      |      |      |      |
|  | 300         | 267                           | 292 | 318 | 356 | 444 | 533  | 622  | 711  |  |      |      |      |      |
|  | 600         | 292                           | 330 | 356 | 432 | 559 | 660  | 787  | 838  |  |      |      |      |      |
|  | 900         | -                             | -   | 381 | 457 | 610 | 737  | 838  | 965  |  |      |      |      |      |
|  | 1500        | 368                           | 419 | 470 | 546 | 705 | 832  | 991  | -    |  |      |      |      |      |
|  | 2500        | 451                           | 508 | 578 | 673 | 914 | 1022 | 1270 | 1422 |  |      |      |      |      |

# THE **PIPING GUIDE**

## **FOR THE DESIGN AND DRAFTING OF INDUSTRIAL PIPING SYSTEMS**

**David R. Sherwood**

Member, American Society of Mechanical Engineers  
Member, Institution of Production Engineers (UK)

**Dennis J. Whistance BS, MS**

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**The 'PIPING GUIDE' .....■ Discusses in detail the design and drafting of piping systems**

- Describes pipe, piping components most commonly used, valves, and equipment
- Presents charts, tables, and examples for daily reference
- Provides a design reference for companies and consultants
- Supplements existing company standards, information, and methods
- Serves as an instructional aid

**PART I - TEXT: explains.....■ Techniques of piping design**

- Assembling of piping from components, and methods for connecting to equipment
- Office organization, and methods to translate concepts into finished designs from which plants are built
- Terms and abbreviations concerned with piping

**PART II - TABLES: provide.....■ Frequently needed data and information, arranged for quick reference**

- Factors for establishing widths of pipeways
- Spacing between pipes, with and without flanges, and for 'jumpovers' and 'rununders'
- Principal dimensions and weights for pipe fittings, flanges, valves, structural steel, etc.
- Conversion for customary and metric units
- Direct-reading metric conversion tables for dimensions

**and .....■ A metric supplement with principal dimensional data in millimeters**

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